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CONVERSATION ON MINES.

W. HOPTON.

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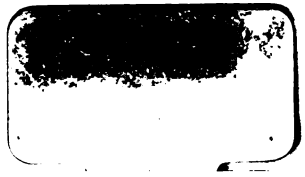

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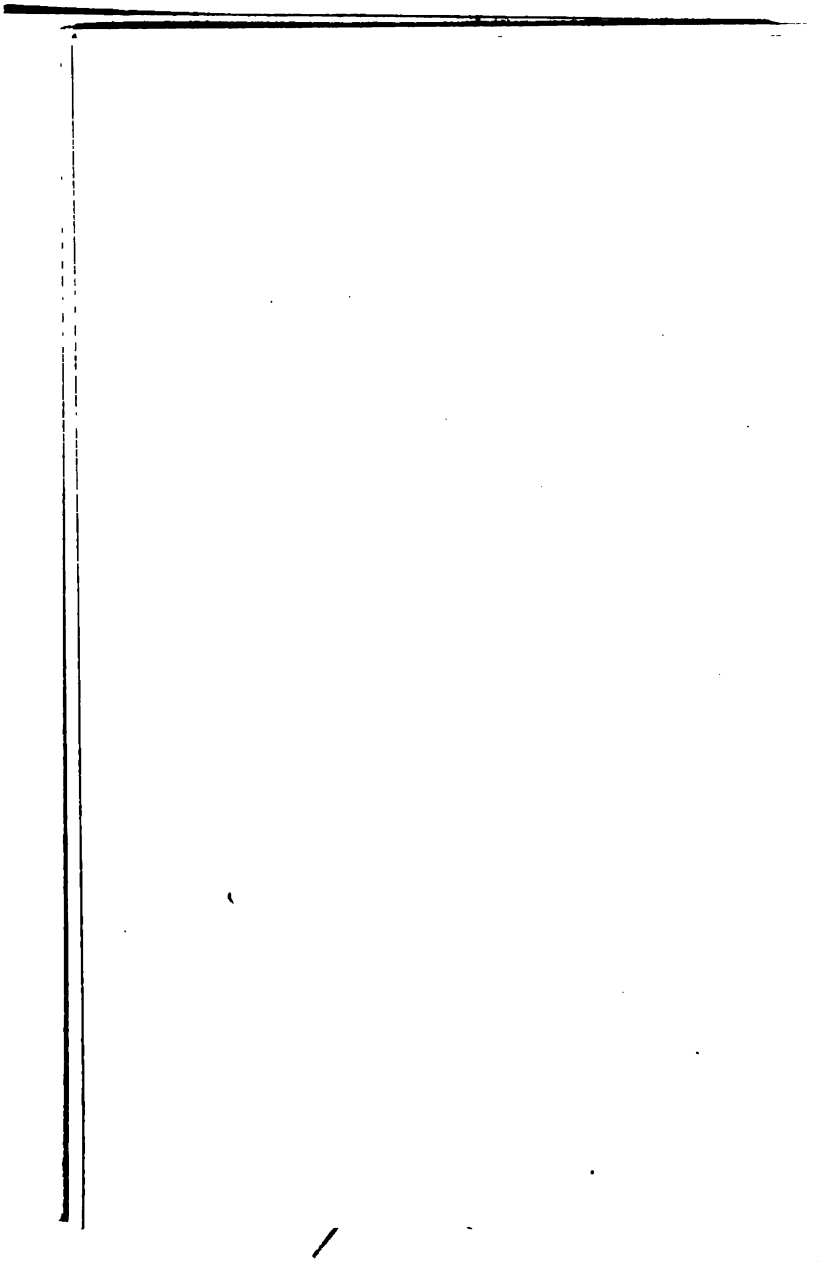

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BY

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CERTIFICATED COLLIERY MANAGER,

Author of "The Lundhill Mode of Ventilation," "A Practical Treatise on Gases, Explosions, Ventilation, and the Workings of Mines," and a successful competitor for Mr. Hermon's Prize of £275. for the best suggestions for the "Prevention" of Catastrophes in Mines; Etc., etc.

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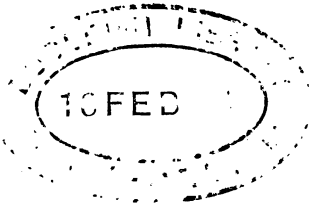
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PREFACE TO THE SEVENTH EDITION.

For the information of young men intending to pass an examination as mine managers, more than three hundred questions and useful calculations have been added to this book, which is now the Seventh Edition, completing the twenty-third thousand copies. Many grammatical errors have been corrected, and the work carefully revised and improved; therefore, it cannot fail to give the greatest satisfaction to the mining public.

St. Helens, 17th March, 1883.

PREFACE TO THE SIXTH EDITION.

In the pages of this work, a clear explanation of every subject on mining is given; the object is to assist persons in the better management and conducting of mines.

The following subjects are clearly and intelligibly explained: how mines generate gases; why the discharge is greater in one mine than another, and how others discharge a mixture of gases; how the weather on the surface of the earth affects the workings of a mine; the power of explosions, and how to diminish it; several ways of ventilating mines, and how currents of air are propelled around the workings; the friction of the ventilating currents, and how to diminish it; with several ways of working out coal, &c., &c.; together with numerous questions and answers on mining matters to assist applicants intending to pass the examination as mine managers, and to assist them in the discharge of their duties.

The great and continued demand for this book is a sufficient proof of its great value to the mining population. Twenty thousand copies have now been circulated, and the book has found its way into every part of the mining world where the English language is spoken.

Helens, 1875.

PREFACE TO THE FIFTH EDITION.

In the space of a few months the fourth edition of the Conversation on Mines between Father and Son has been sold; and the fifth edition, completing Fifteen Thousand Copies, is now printed.

St. Helens, 1873.

PREFACE TO THE FOURTH EDITION.

THE fourth edition is improved with tables of calculations, rules of measurements, and much information on mines added.

The work is a useful companion to all engaged in mining, and it will recommend itself to every person if only perused. The Conversation on Mines between Father and Son has become a household word in every colliery and mining district; and no work on mining was ever so successful as it, ten thousand copies being now circulated.

St. Helens, 1873.

PREFACE TO THE THIRD EDITION.

HOPTON'S Conversations on Mines between a Father and Son is again sold off, and large orders are daily sent in from every mining district in the British Islands, and also from America.

It is from request that the Author publishes this Third Edition of his work, the demand for the same being so great.

When Mr. Hopton wrote the work it was not with the intention, neither did he ever expect it to have been published in the form and style it now appears, but only in articles suitable for public newspapers; and not before eleven hundred copies were ordered did he consent, after much request, to have it published as it now appears.

At the age of seven years Mr. Hopton laboured in mines, and at twenty-one years of age he was engaged to take charge of the underground workings. His son, also, is underground viewer under him, and the son of a "colliery proprietor" is also with him, learning the duties of mine management, so that he, Mr. Hopton, knowing what young men require, is well able to supply their need, having had long experience in mining.

The value of the work may be known by its great demand, and among those who have purchased it, many speak of its value.

December, 1867.

PREFACE TO THE SECOND EDITION.

THIS work, Conversations on Mines between a Father and Son, is now being circulated in every mining district in the British Islands, also in some of the mining districts in America, and other foreign countries; and as the author has orders on hand for several hundreds of copies, he is induced to publish this second edition, the first edition being sold off in a very short time.

The work was written for the better information of underlookers, deputies, firemen, and miners, as it is well known that the generality of them are ignorant of that information respecting mines which they ought to have.

To make the work efficient and complete, for the information of those for whom it was written, the author has spared neither time nor expense.

A great number of testimonials to the work have been received from colliery masters and managers, many of them having supplied copies to their officials and intelligent miners in their employ. Great loss of life has been caused by the ignorance of miners; therefore, to give them the knowledge they so much need, will no doubt prevent loss of life in future.

PREFACE TO THE FIRST EDITION.

THE object which a writer should endeavour always to accomplish is, to make use of such words that every reader may properly understand him, and profit by reading his works.

If the public, or that class of people for whom a work is written, cannot well understand the words written, they cannot profit by the reading, and the labour and time of the author are spent in vain. Therefore, to profit any class of people, in writing works for their better information, it is well if the writer have a knowledge of what such people are capable of understanding; for St. Paul says, 1st Corinthians, 14th Chapter, 9th verse, "Except ye utter by the tongue words easy to be understood, how shall it be known what is spoken? for ye shall speak unto the air." Also, 11th verse, "Therefore if I know not the meaning of the voice, I shall be unto him that speaketh a barbarian, and he that speaketh shall be a barbarian unto me." The words made use of may be proper and good, but are not profitable, if those for whom they are intended cannot understand the meaning of them. Many valuable works have been written on mines and mining by men of talent, but many such works are not understood by

miners, who are generally not well educated. The author, having had a practical knowledge of mines and of miners from his youth, has, therefore, a better knowledge of what miners require for their better information. The object of his writing the following pages on mines, by the way of a conversation between father and son, has been to make use of such words, and in such a manner, that the subject can be perfectly understood by miners. If the end for which the author has written be accomplished, his labour and expense will not be in vain.

St. Helens, Lancashire, April, 1864.

St. Helens, March 14th, 1864.

The undermentioned persons have examined the Plans, &c., connected with the work, and have unanimously pronounced them to be of great practical utility, and the work to be one which has hitherto been much needed by miners at large.

JAMES JERVIS.	ROBERT WOODWARD.
THOMAS HURST,	FRANCIS LYNN.
ROBERT KENYON.	THOMAS ROSBOTTOM.
ALFRED MICKLETHWAITE.	GEORGE PENNINGTON.

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Any communications for the Author, addressed care of MR. CHARLES THRUSH, No. 60, Denton's Green Lane, St. Helens, will be duly received.

A CONVERSATION ON MINES.

The Nature and Properties of Gases.

Son: As you have been in mines, father, from early life, and your ancestors have had, during generations past, a practical knowledge of them, I shall be glad when convenient to have a little conversation with you on mines.—*Father:* If I can give information by which you and the public may profit, I shall have great pleasure in so doing; and as we have a little leisure just now I shall be glad to answer, to the best of my abilities, any question you require information on respecting mines and mining.

Son: Very good. Then I wish to know, father, if carbonic acid gas, which miners call black damp, and the gas left in mines after an explosion, be one and the same?—*Father:* No. Gas left after an explosion is called after-damp or choke-damp, and is much lighter than black-damp, or even common air. This gas will make its way up to the roof, while black-damp will lie near the floor. Carbonic acid gas is a combination of carbon and oxygen. It was formerly called fixed air, on account of its being found in chalk, limestone, magnesia, &c.

Son: What are the properties, father, of carbonic acid gas?—*Father:* Carbonic acid gas (black-damp) is invisible; it is

incombustible and inexplosive, and unfit for respiration. It is a positive poison; it lays violent hands upon its victim, and at once kills him. It is one of the ingredients of after-damp.

Son: What is its composition?—*Father:* It is found to consist of six parts, by weight, of carbon, united with 16 parts of oxygen.

Son: Do you know the composition, father, of after-damp, or choke-damp, as you say it is lighter than black-damp?—*Father:* It is formed of two parts by volume of watery vapour, one of carbonic acid, and eight parts of nitrogen, nitrogen being lighter than atmospheric air, and therefore much lighter than black-damp. The nitrogen, you know, is one of the ingredients of the air.

Son: Is there any other kind of gas discharged in mines that you know of?—*Father:* There is the stone, or white gas.

Son: White gas! What kind is that?—*Father:* This gas is not explosive, nor a gas that will put out the candle blaze; the candle burns well in it, but will not explode it. It is poisonous and would soon kill a person. This gas is produced at the time of blasting rock, when gunpowder has too much work. Much of it is discharged also when spontaneous combustion at first takes place in mines. Its proper name is sulphuretted hydrogen.

Son: Have you ever seen such gas?—*Father:* I have several times been affected by it, and have been informed of it by those who have seen it; also a deputy under me had the sinking of a shaft in which this gas was given off, and two of the men sinking with him were lost, and he himself was nearly lost—after a shot.

Son: Have you ever experienced the effects of these gases? Some people say they have a choking nature.—*Father:* I have often been affected by the gases, and have had to be brought

home, having been rendered insensible by them, but I never felt the choking sensation that one would expect.

Son: Brought home insensible! Had you much pain, then, before you became insensible? or do you remember anything of what took place?—*Father:* I remember well that I had no pain, and was very sick for a moment or two just before I lost all sensation. My limbs also felt very heavy, so that I was not able to use them.

Son: Would you then be like a person insensible with sleep? Just as a person is not conscious of the moment he passes away into sleep, I presume you would have no knowledge of the moment you passed into insensibility? But how long were you in that state of unconsciousness?—*Father:* I cannot say how long I had been insensible, as I had been brought up out of the pit, and was at home when I returned to consciousness. I had been at home a long time before my knowledge of things returned properly, and at the moment of my recovery every person I saw appeared as in a dream.

Son: By this, I presume, father, that in explosions all persons lost through the effects of after-damp suffer very little at death, as they pass away like a person in sleep?—*Father:* I believe they know very little until death passes them into eternity. I know that had I remained in the pit a little longer I should have passed away without a knowledge of it.

Son: Is carburetted hydrogen gas called by miners explosive gas?—*Father:* Yes, some call it explosive gas, others fire-damp, and others fire.

Son: What is the composition of the gas burnt in the streets?—*Father:* It consists of four parts of hydrogen, and two of carbon by volume.

Son: What is the composition of carburetted hydrogen gas, or explosive gas?—*Father*: It consists of four parts of hydrogen, and one of carbon.

Son: Will this gas ignite if not mixed with atmospheric air?—*Father*: No. It is combustible only in oxygen or air. One foot of carburetted hydrogen gas requires to be mixed with from five to twelve feet of air before it will ignite.

Son: Do not miners' candles burn with enlarged flames when working where explosive gas accumulates?—*Father*: The flame of the candle is enlarged when air and gas are in such quantities as to be nearly an explosive mixture. When one foot of gas is mixed with 13, 14, 15 or 16 feet of air, the candle burns with enlarged flame; but by mixing more air to the one foot of gas, the flame of the candle diminishes to its proper size.

Son: Gas, then, is rendered harmless by *adding* more pure air to the one foot of gas?—*Father*: Just so. It becomes further from the explosive mixture by adding more pure air to it. An expert person may see a cap on the candle so small that twenty times as much gas might be added before the mixture of gas and air would be at an explosive point.

Son: What quantity of air does gas require to make it, *when ignited*, at the greatest explosive mixture or power?—*Father*: One foot of gas mixed with seven to ten feet of air is near the greatest explosive mixture, or one foot mixed with two of oxygen.

Son: If a miner's working place is full of gas, will the air destroy it if mixed with it?—*Father*: No; air will not destroy gas, but only render it harmless, if the volume of air be much greater than that of the gas. That is, if twenty feet of air, or more, be mixed with one foot of gas, then, in such mixture the gas is rendered harmless.

Son: It requires, then, a larger volume of air than of gas to cause an explosion, and a larger volume, also, of air, to *prevent* an explosion? which looks like a contradiction.—*Father:* Such is the case. As before stated, a mixture of from five to twelve feet of air to one foot of gas will cause an explosion; but a larger mixture of air to the same quantity of gas will prevent one.

Son: Is explosive gas elastic?—*Father:* Yes. Three feet of gas may be pressed into the space of one foot; or if the pressure be reduced sufficiently, the three feet will expand into six feet or more. Air can be pressed into 40,000 times less space than it naturally occupies, and expanded to 14,000 times larger than it usually occupies.

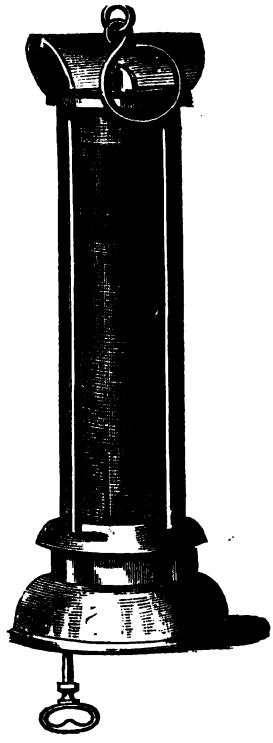
Son: Then, when the weight of the air is reduced, the gas expands and issues out of the strata, out of every hole in the roof, and out of the old goaf (which may be called magazines of gas), and overflows into the workings and tramroads from every place wherein it is compressed?—*Father:* Yes; that is the reason that mines produce more gas at one time than at another, and also more when a change in the weather takes place.

Son: Why does explosive gas make its way up to the roof in mines, and fill holes and stock-working places which lie highest?—*Father:* Because explosive gas is much lighter than air. Two feet of the gas will weigh only a little more than one foot of air, because the specific gravity of atmospheric air is 1·000, and that of explosive gas, 0·555.

Son: Why does carbonic acid gas, which miners call black-damp, lie nearest the floor in mines?—*Father:* Because it is heavier than air. One foot of it is nearly as heavy as two feet of air; its greater weight being the cause of its lying nearest the floor. Its specific gravity is 1·524.

Son: If black-damp be heavier than air, how can the air current drive or propel it along, through the workings and up the upcast? Will not the air pass through and the gas settle downwards to the botton, like mud in water?—*Father:* Unless the current of air pass through the workings and along the air-passages, with a propelling force sufficient to overcome the greater weight of the black-damp, it cannot clear the mine, and the black-damp will settle down, as you say.

Son: Safety lamps are often used, are they not, in those mines discharging explosive gas?—*Father:* Yes, and great loss of life has often been *prevented* by the use of safety lamps; and yet many lives have been lost, I fear, by too much reliance on the safety lamp, when the purity of the current ought to have been attended to by rendering the gases therein harmless.



Son: No doubt, then, you have seen safety lamps used in mines?—*Father:* Seen them? yes, thousands of times. This is a representation of Stephenson's lamp.

Son: Have you seen gas explode inside the wire-gauze, and not explode the gas outside?—*Father:* Yes, very often; I remember well on one occasion, gas came suddenly upon a person and me, and our lamps filled

with flame; we lowered the cotton-wick to put out the blaze, but the flame remained within the gauze.

Son: And what did you do then?—*Father:* We got into pure air and a safe place as soon as possible, but not before the lamps were red hot, for we had to take them one hundred yards or more.

Son: I think the safety lamp a very good invention. Do you know, father, why flame will not penetrate through the wire-work, and explode the gas outside?—*Father:* Because the inflamed gas within is so much cooled in its passage through, or by its contact with the gauze, as to cease to burn before it reaches the gas outside.

Son: I do not see, yet, why an explosion taking place within the gauze should not communicate to, and explode the gas around it?—*Father:* This is a subject of wonder to even philosophers, and the only mode they have of explaining it is, that flame cannot pass through fine wire-work, because the wire cools the flame sufficiently to extinguish it in passing through.

Son: But does not the wire often become red hot, by the burning of the gas inside?—*Father:* Yes, but fortunately gas cannot be exploded by red hot wire, the intervention of actual flame being required for that purpose, so that the wire cannot set fire to the explosive gas around it.

Son: But if the wire be red hot, how can it cool the flame within, and prevent it passing through the gauze?—*Father:* The gauze, though red hot, is not so hot as the flame by which it has been heated.

Son: Is it not possible, then, to propel the flame through the gauze?—*Father;* A strong current of air will propel it through.—*See Table A. page* 20.

A.—The following is an extract from the Register of Experiments on Safety Lamps at Hetton Colliery, conducted by the Lamp Committee of the North of England Institute of Mining Engineers, 14TH OCTOBER, 1867.

No.	No. per Register Book.	Lamp.	Velocity of Current. Feet per second.	Time of Duration of Experiment Seconds.	Position of Lamp.	Remarks.
1	1	Common Davy	11½	2	Perpendicular	Fired
2	15	Morrison's No. 1	15	90	Do.	Still burning (gas turned off)
3	16	Do. 2	14	5	Do.	Out
4	17	Do. do.	do.	2	Do.	Do.
5	18	Do. do.	18	4	Do.	Do.
6	19	Do. do.	21	24	Do.	Do.
7	20	Do. do.	25	23	Do.	Do.
8	21	Do. 1	do.	35	Do.	Still burning (gas turned off)
9	22	Do. do.	35	2	Do.	Out
10	23	Do. 2	do.	3	Do.	Do.
11	24	Do. 1	do.	1	Slanted top from current.	Do.
12	25	Do. 2	do.	1	Do.	Do.
13	33	Do. 1	do.	5	Do.	Do.
14	41	Do. 2	25	5	Perpendicular	Do.
15	42	Do. 1	do.	11	Do.	Do.
16	43	Do. do.	do.	2	Do.	Do.
17	46	Do. do.	do.	3	Slanted top from current.	Do.
18	50	Do. 2	20	Not ntd	Perpendicular.	Gas turned off by mistake.
19	51	Do. 1	do.	10	Do.	Out
20	52	Do. 2	do.	2	Do.	Do.
21	55	Do. 1	27	50	Slanted top to current.	Still burning, gas done.
22	56	Do. 2	do.	6	Slanted top from current.	Out
	57	Cail & Glover	do.	2	Perpendicular.	Fired
	62	Geordie, with protg. shield	do.	5	Do.	Do.

Son: You say the engraving is a representation of Stephenson's lamp. Is not this lamp like all others ?—*Father:* Stephenson's lamp is so constructed as to extinguish the flame the moment gas explodes within it, so that the gauze can never become red hot.*

How Gases are Discharged, Accumulated, and Produced in Mines.

Son; What is meant by discharging, producing, and accumulating; that is, what am I to understand, father, by the same, as people often say mines discharge, produce, and accumulate gases ?—*Father;* You must understand by the word "discharge," to produce from, to form, or to cause. The word "accumulate" means to increase, to collect, or bring together, or to make more.

Son: But how are gases produced, or accumulated in mines ?—*Father:* There are two ways by which gases may be said to accumulate in mines. All gases are produced, you know, from every stratum, from one end of the whole route of the air-passages to the other. When the air first enters the air-gate, at the down-cast, there is in the first yard of its route a supply of gas. More gases are added as the air passes onwards. Let it pass still forward, and the quantity multiplies; yet, as the air goes still onward, the flow of gas from every stratum increases

* On the 20th of February, 1872, an Improved Safety Lamp, invented by Henry D. Plimsoll, Esq. of London, was subjected to some severe experimental tests, performed by Mr. William Utley, underviewer at the Wombwell Main Collieries, Barnsley, the inventor (Mr. Plimsoll), myself, and other friends; and the issue of the experiments was so successful that I have no hesitation in giving an opinion to the effect of its being the best safety lamp yet invented, as the following qualifications, which were fully borne out by the result of the tests, will amply show:—I. It is very sensitive to gas. II. The moment an explosion takes place within the lamp, its light is thereby extinguished. III. By unscrewing the lamp top the light is extinguished, therefore there is no inducement for miners to tamper with it. IV. It gives a very much clearer and purer light. V. The force of the current cannot extinguish its light, be the velocity ever so great. VI. Should an explosion take place within the lamp, there is no possibility of the current propelling the flame outside.

the quantity in the air, until the mixture of air and gas is discharged at the top of the up-cast. This is one way by which gases accumulate; and the other is, when air cannot get at and pass through any stocked or undisturbed part of the mine to bring gas away from it. If the air in a mine should at any time become stagnant, the mine would very soon fill with gases.

Son: In those mines, then, where much gas is produced, and there is not a proper quantity of air to dilute it, and bring it away, the accumulation will be very great.—*Father:* Yes: there is always an accumulation of gas going on in mines, if the quantity of air be not sufficient to dilute and render it harmless.

Son: Is there any weight on the strata of coal and stone from where gas is produced, to compress the said gas therein?—*Father:* There is the atmospheric weight or pressure always pressing against the strata from whence it is discharged.

Son: What is the pressure of the atmosphere against the strata?—*Father:* The pressure is nearly 15lbs. upon every square inch of the surface of the strata; 2,160lbs. upon one square foot; 5,000 billions of tons pressing upon the whole earth's surface.

Son: Is the amount of gas discharged in mines, then, in *proportion* to its overbalancing pressure?—*Father:* Yes. The escape of gas in mines is like steam blowing off from a boiler. When steam is much compressed in a boiler, the compressed steam, you know, will lift up the weight of the valve, which presses it there, and it will continue to blow off therefrom until its compression is reduced to the weight of the valve; in like manner, then, gas blows out and escapes from the strata, because its compression therein is greater than the weight of the atmosphere.

Why one Mine discharges more Gases than another.

Son: Why do not all mines give off explosive gases alike in quantity, when the atmospheric weight is equally reduced from the strata in all mines?—*Father:* The atmospheric weight is equally reduced from the strata, but the "compression" of gas is not alike in all mines; therefore, the discharge of gas is not alike.

Son: I cannot see why all mines do not discharge the same quantity, when the weight which presses in the gas is reduced alike in all.—*Father:* Well, for your better information, I will illustrate the case. Suppose three boilers are full of steam, the weight of each valve 15lbs., the steam in one boiler so compressed that a great quantity of steam blows off; another, not so compressed, blows off less steam; and a third blows off very little, because little compressed. Now, by taking 1lb. weight from each valve, the greatest quantity of steam will blow off from the one most compressed; so, in like manner, most gas will escape in those mines where it is most compressed.

Son: Very good, that I understand; but why, father, is not the pressure of gas in mines alike?—*Father:* Because the gas has been blowing off longer in some than others.

Son: Will not the great pressure of gas in the strata all blow off in time (as steam blows off from a boiler) until the pressure of gas be the same as the pressure of the atmosphere?—*Father:* Yes, in time the two will become equal in pressure.

Son: By this I understand the pressure of gas in the strata will become so reduced, that it will press out with only a 15lb. pressure, like the 15lb. pressure of the atmosphere which presses it there, the two then being equal?—*Father:* Yes; after the

the quantity in the air, until the mixture of air and gas is discharged at the top of the up-cast. This is one way by which gases accumulate; and the other is, when air cannot get at and pass through any stocked or undisturbed part of the mine to bring gas away from it. If the air in a mine should at any time become stagnant, the mine would very soon fill with gases.

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Son: Is there any weight on the strata of coal and stone from where gas is produced, to compress the said gas therein?—*Father:* There is the atmospheric weight or pressure always pressing against the strata from whence it is discharged.

Son: What is the pressure of the atmosphere against the strata?—*Father:* The pressure is nearly 15lbs. upon every square inch of the surface of the strata; 2,160lbs. upon one square foot; 5,000 billions of tons pressing upon the whole earth's surface.

Son: Is the amount of gas discharged in mines, then, in *proportion* to its overbalancing pressure?—*Father:* Yes. The escape of gas in mines is like steam blowing off from a boiler. When steam is much compressed in a boiler, the compressed steam, you know, will lift up the weight of the valve, which presses it there, and it will continue to blow off therefrom until its compression is reduced to the weight of the valve; in like manner, then, gas blows out and escapes from the strata, because its compression therein is greater than the weight of the atmosphere.

Why one Mine discharges more Gases than another.

Son: Why do not all mines give off explosive gases alike in quantity, when the atmospheric weight is equally reduced from the strata in all mines?—*Father:* The atmospheric weight is equally reduced from the strata, but the "compression" of gas is not alike in all mines; therefore, the discharge of gas is not alike.

Son: I cannot see why all mines do not discharge the same quantity, when the weight which presses in the gas is reduced alike in all.—*Father:* Well, for your better information, I will illustrate the case. Suppose three boilers are full of steam, the weight of each valve 15lbs., the steam in one boiler so compressed that a great quantity of steam blows off; another, not so compressed, blows off less steam; and a third blows off very little, because little compressed. Now, by taking 1lb. weight from each valve, the greatest quantity of steam will blow off from the one most compressed; so, in like manner, most gas will escape in those mines where it is most compressed.

Son: Very good, that I understand; but why, father, is not the pressure of gas in mines alike?—*Father:* Because the gas has been blowing off longer in some than others.

Son: Will not the great pressure of gas in the strata all blow off in time (as steam blows off from a boiler) until the pressure of gas be the same as the pressure of the atmosphere?—*Father:* Yes, in time the two will become equal in pressure.

Son: By this I understand the pressure of gas in the strata will become so reduced, that it will press out with only a 15lb. pressure, like the 15lb. pressure of the atmosphere which presses it there, the two then being equal?—*Father:* Yes; after the

pressure of gas has been reduced there, the two will become equal.

Son: If the pressure of steam in a boiler was reduced to the same weight on the valve,—say if the two were each equal to 15lbs., no steam then, I presume, father, would blow off, as it could not remove away that which was equal in pressure to itself?—*Father:* No; in that case there would be no blowing away of steam, for it could not (as you say) lift off a pressure equal to itself.

Son: Then I presume no gas will escape in a mine after the pressure has become equal to the atmospheric weight?—*Father:* I do not wish you to understand that *no* discharge will take place; yet very little will be discharged after the pressure has been so reduced.

Son: I cannot see how any gas can make its way out when its pressure is reduced to the atmospheric weight. It cannot lift away the atmospheric weight to make its escape.—*Father:* To look at it that way it would appear no discharge could take place. But you know the atmosphere, as before stated, is always changing. To-day its weight may be 15lbs.; to-morrow, little more than 14lbs. Therefore, when its weight is reduced from 15lbs. to 14lbs., the discharge of gas then takes place. The weight of the boiler valve is stationary, and cannot be pressed into the boiler; but air can be pressed into the strata, and works in and out at every change of the barometer.

Son: I see a little would be discharged, but only until its pressure was reduced to the lowest atmospheric weight.—*Father:* When gas is reduced in the strata to the lowest atmospheric weight, say to nearly 14lbs., and the atmosphere returns to its former weight of 15lbs., the atmosphere itself is then pressed

into the strata to fill up the space of that gas which escaped when the atmosphere was at its lowest pressure.

Why some Mines discharge a Mixture of Carbonic Acid Gas (Black-damp) and Explosive Gas.

Son: Do all mines give off the same sort of gas?—*Father:* No. One discharges carbonic acid gas, which miners often call black-damp; another explosive gas, which miners call fire-damp. But other mines discharge a mixture of the two gases.

Son: I wish to know if all mines make the same quantity of explosive gas—that is, those which give off explosive gas?—*Father:* No; one gives off a great quantity, another not so much, and a third very little.

Son: You said just now, father, that the weight of the valve is not like air. When the pressure of gas is reduced below the atmospheric weight, is air pressed into the strata to fill up the space or vacuum which is thus caused, and also to balance the pressure of the atmosphere?—*Father:* Yes. The air works in and out of the strata, and mixes with the gas therein, because the same reduced weight which caused gas to expand and work out, will also press air in. The atmospheric weight is never long at a standstill, but works backwards and forwards against and into the strata, like a man breathing, taking in and letting out air.

Son: Do you wish me to understand by this that the strata afterwards gives off a mixture of air and explosive gas?—*Father:* I wish you to understand that when gas is so reduced, the strata gives off a mixture of explosive gas and black-damp.

Son: Is the confined air, then, which was pressed into the strata, converted into black-damp?—*Father:* I believe such is the case. You know a man by breathing lets air into his body, and that air, when let out, is converted into nitrogen and carbonic acid, so in like manner, the confined air is, no doubt, converted into carbonic acid gas, or black-damp.

Son: Then mines like this discharge a mixture of explosive gas and black-damp?—*Father*: Just so. They discharge the two gases until the explosive gas is exhausted, after which the mine discharges black-damp only.

Son: Is it not surprising? I see very clearly now, how one mine produces explosive gas, another a mixture of gases, and a third black-damp, or carbonic acid gas. But have you seen air pressed into the strata the way you show?—*Father:* I have several times seen air enter into open spaces in coal, stone, and rock, which drew in a candle-flame, and the next day the same open space which drew in the air gave off a mixture of gases, and by observing them, I found the open spaces alternately gave off gases and let in air as the weather changed.

Son: Have you seen any other thing to convince you that the air passed in and out of the strata?—*Father*: Yes; a number of men under my charge were working one day near to the workings of an old colliery. They holed into them, and when they got through, air passed in as if it were rushing to an up-cast near at hand. This enabled me and others to travel a great distance on the tramroads belonging to the old workings. The men with me were at a loss to know why air entered through the hole; but as I knew it was only a return of the weight or pressure of the atmosphere, I told them not to be surprised if to-morrow black-damp rushed out of the hole from the old working.

Son: And was such the case?—*Father:* Yes. One day we were able to travel into the old tramroads a great distance; another day we were not able to get to the hole from whence damp came out. It was like a weather-glass, or barometer, for the men.

How a Change in the Weather Affects the Workings of a Mine with Gases.

Son: Why are mines affected by a change in the weather?—*Father:* Because when the barometer falls the weight of the atmosphere which presses gas in the strata is diminished. When a change in the weather takes place, the weight of the atmosphere is diminished from 15 lbs., to say nearly 14 lbs. This diminishing in weight of the atmosphere causes an extra discharge of gas, just as an extra discharge of steam would blow out of a boiler if a little weight were taken off the valve. The moment the pressure of the atmosphere is reduced, gas expands and forces its way out from every place wherein it is compressed.

Son: Do not miners often say, on seeing a cloudy wet morning, they will not be able to work that day? and also say so when the wind blows in a certain direction?—*Father*: Yes; the miner knows that the weather affects his working place, but he has not the knowledge to enable him to understand how it does so.

Son: Are all working places so affected as not to allow the men to work when a change of weather takes place?—*Father*: All are more or less affected, but all are not so much affected as to prevent men from working in them.

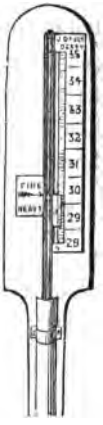
Son: Why are not all affected alike?—*Father*: Because some have very little air for ventilating purposes—only just sufficient

to take the gases away on those days when little is discharged. Therefore, when a change of weather takes place, the air is not sufficient to dilute the extra quantity of gas that is discharged.

Son: I see that much caution and care are required to prevent explosions. Is there any forerunner to give notice to the men when a change in the weather takes place, so as to give a knowledge of the extra discharge of gases?—*Father:* The barometer will show when a change in the weather takes place, but will not show before the extra discharge of gas commences. The change in the two is at one and the same time. Therefore, there is nothing to give notice beforehand. I have known an extra discharge of gas to take place even before any change has been seen in the barometer. This shows that the gas is "more sensitive" than mercury.

Son: Will you give me a little explanation of the barometer, so that I may understand by it the changes in weight, or pressure of the atmosphere? Such information will give me a knowledge when the weight is reduced which gives place to an outburst of gas, and as a larger quantity is discharged from the strata, at such a time, the knowledge is important.—*Father:* The diagram you see is a representation of the barometer; when a change in the weight of the atmosphere takes place, the fluid or mercury within the tube is set in motion, it moves up or down at every change of the atmospheric weight.

Son: How is the mercury within the tube set in motion by the atmosphere?—*Father:* It has been discovered that water cannot be raised more than about 34 feet in the suction-pump, the weight of the atmosphere on the surface of the water being the cause of the ascent of water in the vacuum made in the pump, and that a column of water 34 feet high is, therefore, an exact



counterpoise to a column of air which extends to the top of the atmosphere. The column of mercury in the barometer is much shorter than 34 feet, because mercury is fourteen times as heavy as water; for if the weight of the atmosphere will balance 34 feet of water, it can balance only (on the same principle) 29 to 30 inches of mercury.

Son: You say "balance," am I to understand by this that the atmosphere and the mercury are balanced similar to two weights in a pair of scales; the mercury being in one scale, and the atmosphere in the other.—*Father:* Just so; 29 or 30 inches of mercury within the tube of a barometer, or 34 feet of water in the pump-barrel, balances the whole weight of a column of the atmosphere, said to extend 45 miles high.

Son: Then when the mercury moves upward there is an increased weight of the atmosphere, and a diminished weight when it moves downwards?—*Father:* Such is the case; you know if the weight in one scale be increased or diminished, the other scale will ascend or descend.

Son: If the mercury within the tube of the barometer moves downwards, I may know that an extra quantity of gas is escaping from the strata, because the weight of the atmosphere which pressed gas therein is reduced?—*Father:* That is the way. I see you understand, now, the barometer. "Fire" on the barometer denotes a large quantity of gas escaping from every stratum in the mine, because the atmospheric weight is reduced. The condition of the air in a colliery depends very much on the weight of the air at the surface. As the weight of the atmosphere is shown by the height of the barometer,

readily see that when the barometer sinks, the air becomes lighter; and the pressure, which before assisted to keep in the gas, being diminished, allows it to escape. For every inch which the barometer falls, the pressure per square foot is lessened more than 70lbs. The following valuable table of Mr. Fairley's will show the matter more clearly:—

TABLE OF THE PRESSURE OF AIR AT DIFFERENT HEIGHTS OF THE BAROMETER.

RULE.—Height of barometer in inches X·4908—weight of a cubic inch of mercury=pressure per square inch in pounds.

Height of Barometer in inches.	Pressure per square inch in pounds.	Pressure per square foot in pounds.
27·	13·25	1908·23
27·25	13·37	1925·89
27·5	13·49	1943·56
27·75	13·61	1961·23
28·	13·74	1978·90
28·25	13·86	1996·56
28·5	13·98	2014·24
28·75	14·11	2031·91
29·	14·23	2049·58
29.25	14·35	2067.25
29·5	14·47	2084·01
29·75	14·60	2102·58
30·	14·72	2120·24
30·25	14·84	2137·92
30·5	14·96	2155·59
30·75	15·09	2173·26
31·	15·21	2190·93

Son: I would be glad to see how these are worked out. Will you please show me an example?—*Father:* Yes. Suppose the height of the barometer to be 27 inches, and we wish to know the pressure per square foot in pounds; then by the rule 27 × ·4908=

13·2516 which is the pressure per square inch, and, multiplying this by 144 we get 1908·2304, the pressure per square foot.

Son: When are mines in the greatest danger ?—*Father:* Some are always in danger, if there is not sufficient pure air to dilute and render harmless the gases.

Son: Yes. But from changes in the weather ?—*Father:* The greatest danger is when there is a sudden fall in the barometer and a sudden rise in the thermometer, at one and the same time.

Son: How is that ?—*Father:* Because a fall in the barometer, as I before stated, gives place to a larger outlet of gas, as the atmospheric weight is then diminished, and a rise in the thermometer lessens the air in the mine, which should dilute and take away the gas. The two taking place at one time is the cause of much danger.

Son: I understand; a rise in the thermometer shows an increase of temperature, or more heat ?—*Father:* Just so. By this rise, the ventilating power is reduced; not only so, but the density of the air is also diminished by both; so that there is not the same quantity of air passing in the current through the *same area* in the *same space* of time. The temperature rises much, you know, from winter to summer.

The Natural Ventilation in Mines.

Son: What am I to understand by a fall and rise of the temperature ?—*Father:* When the mercury in the thermometer stands at 32 degrees, the temperature is at freezing point, below that is extreme cold; 55°, is temperate heat; 76°, summer heat; 98°, blood heat; 112°, fever heat; at 176°, spirits boil; and at 212° water boils.

Son: I see now, if the temperature should suddenly rise from say, 32 to 60 degrees, the change would be very great, and might cause people to sweat much; but to fall from 60 to 32 degrees would cause an extra coat to be required?—*Father*: Just so. I find you understand the rise and fall of the temperature; it oftens rises and falls suddenly in England.

Son: I understand it, because I have had a practical knowledge of such changes. Can you give me the lowest, and also the highest degree of temperature in each month for one year? Any year will do.—*Father:* Yes; I will try to give them to you. But I wish you to understand that the temperature is not equal, on the same day, in every part of England; the temperature of one place may vary a few degrees from that of another. Therefore, I will give the temperature at Manchester for each month in the year 1852.

	Lowest.		*Highest.*	
	Dates.	*Degrees.*	*Dates.*	*Degrees.*
January.....	12th	21	15th & 21st	50
February.....	11th & 21st	29	24th	54
March.....	8th, 9th, & 11th	30	23rd	61
April.....	4th	33	15th	64
May.....	4th	34	8th, 17th, 20th, & 24th	64
June.....	1st	42	6th & 20th	69
July.....	23rd	51	4th	83
August.....	11th	50	1st & 17th	71
September...	17th	38	5th & 8th	70
October.....	8th	35	22nd	60
November ...	29th & 30th	32	8th	61
December.....	8th	31	5th	56

Son: Many thanks for the information. The temperature changes a good deal from summer to winter. The lowest in that year, I see, was 21, and the highest 83 degrees—one very cold,

the other very hot. I think the temperature in the underground workings of mines does not so change. I have seen miners, in going down the pit in winter, all anxious to go down at once, if possible, to get out of the cold, the mine being warm, but in summer the mine is cooler than on the surface. Why is it so?—*Father:* The underground workings may appear on first entering cooler in summer than in winter, but it is not so; the temperature of the mine is nearly the same all the year round, unless more men are employed, and the works more extended. It is you only who feel the change in passing from a high temperature, on hot days in summer, to a lower one, but in winter from a low temperature to a higher one.

Son: Is the temperature equal in all mines?—*Father:* No; the temperature is much higher in some mines than in others.

Son: Why is it much higher in some than in others?—*Father:* Because more men and horses are employed in some than in others. The pits are deeper, and the works more extensive, &c., &c.

Son: How is heat produced by men, horses, deep mines, &c.?—*Father:* The temperature of mines is due to several causes. At a certain depth from the surface, the temperature in England is invariable throughout the year, and does not sensibly differ from the mean annual temperature, which may be taken at 50 deg. F. Below this "line of no variation," the temperature continues to increase as we descend. The general result obtained by a comparison of many observations shows that the increase of temperature is—

In the first 200 yards...	about 1 deg. F.	for every	50ft.
In the second 200 yards...	do.	do.	70ft.
In the third 200 yards.....	do.	do.	85ft.

Also miners, by respiration, produce heat, and their lamps produce nearly the same amount; again, there are various chemical actions going on, each of which is a source of heat; there is also slack or rubbish left in heaps for a considerable time, from which heat is thrown off.

Son: I shall be glad to be informed the height to which the temperature in mines is raised. I should then know nearly the lowest and the highest temperature on the surface, and also the highest temperature raised by natural heat in mines.—*Father:* I can give the highest natural heat of several large collieries; and, I think, the highest known to have been produced. Some mines, as you know, produce more natural heat than others.

Son: Is the natural draught or the natural ventilation produced by natural heat?— *Father:* Yes. The natural heat of mines is the power or cause, and the natural draught the effect produced by that cause. Remove the cause, and the effect will cease.

Son: I remember a good deal has been said in reference to this natural ventilation in mines. Some say there is a constant natural current all the year round, and others say there is not; therefore, I should like to ask a few questions on the subject. Do you know the highest degree of the natural heat in mines?— *Father:* The temperature of the down-cast at the cannel pit, Ince Hall, Wigan, on the 13th of January, 1853, was 42 degrees, and the temperature of the workings was 62 degrees. This will show the natural heat of the mine to be 20 degrees higher than the air at the down-cast. On the 16th of December, 1852, the temperature at the down-cast pit at Seaton Delaval Colliery was 42 degrees, and the average temperature of the mine 50 degrees, or 8 degrees above the air at the down-cast. At the Tyne Main

Colliery, when an experiment was made, the natural heat of the mine showed a difference of 20 degrees between the down and up-cast shafts. At the Hetton Colliery, the natural heat of the mine was found at one experiment to produce between the down and up-cast shafts a difference of 28 degrees; but this experiment was made at a time when the temperature on the surface was very low. I am only sorry that the temperatnre on the surface at the time was not given. To fix the temperature, then, on the surface, at 34 degrees, when the experiment took place at Hetton Colliery, it would show the natural heat of the mine to be 62 degrees, the same as at the cannel pit, Ince Hall, Wigan. Thus we arrive at nearly the highest temperature produced by the natural heat in mines.

Son: Is not the natural heat, then, constant in mines?—*Father:* Yes, always the same, summer and winter.

Son: Then if always the same, will it not always produce the natural draught?—*Father:* No; the natural draught is diminished or increased, according to circumstances.

Son: Pray let me know what those circumstances are; for I cannot see why there is not always the natural draught in mines when the natural heat by which it is produced is always the same?—*Father:* Let me first show when the natural draught is there, after which I will show when it is not.

Son: That is just what I wish you to do.—*Father:* Well, you remember I have just stated that the temperature of the mine is sometimes 20 or even 28 degrees higher than the temperature of the air coming from the down-cast.

Son: I remember.—*Father:* When that is the case—that is, when the temperature of the underground workings is higher than the air on the surface—there is always the natural draught.

In winter, when the air is extremely cold, it produces a large current. You know if the temperature on the surface be down at 30 degrees, and the air in the mine 62, the heat will be 32 degrees above that on the surface. This would give a large natural current.

Son: How does the natural heat produce the current?—*Father:* Heat, you know, as I have often stated, expands the air so that one cubic foot of warm air is not the same weight as one cubic foot of cold air; therefore, warm air being much lighter than cold, it rushes up the up-cast as corkwood in water, or as a balloon through the air.

Son: I see now how the heat of the mine produces the natural draught, but what has the heat of the mine to do with the cold air on the surface?—*Father:* Well, it has this to do with it. When the cold air on the surface descends into the mine, it is increased in temperature, and thus the natural current is produced. You know, if the temperature of the air on the surface was, say 33 degrees, there could not be an increase in temperature by passing it to a mine where the natural heat was 62 degrees.

Son: In that case the natural heat of the mine would not be above, but below the temperature of the air on the surface.—*Father:* Just so. I will illustrate the case. Suppose it were winter, and you had a pair of scales so large and so constructed that you could put in one scale all the hot air that filled the up-cast shaft, and in the other all the cold air which filled the down-cast shaft.

Son: By this illustration I can see your object. You said that one foot of warm air weighs much less than one foot of cold air.—*Father:* I did. Therefore, if you balance the hot and the cold air, you will find the cold air in the down-cast scale will

outweigh the hot air in the up-cast scale; but suppose it is summer, when the temperature of the air on the surface is, say 83 degrees, and you fill your down-cast scale with this hot air, will this expanded air, at 83 degrees, overbalance the air in the up-cast scale, at 62 degrees? No, impossible, unless there is another power or weight in the scale to assist in weighing it down. I can no more believe it than I can believe 1 lb. will weigh down 2 lbs.

Son: I think it is clear enough to be seen by every person. As you say, the natural heat of the mine being much higher in temperature than the air on the surface, the cold air, in passing through the workings to the up-cast, is much expanded by the heat of the mine, and therefore a cubic foot of hot expanded air (in the up-cast) is much less in weight than a cubic foot of the heavy cold air (in the down-cast); and, as there is not the same weight in one as in the other, one falls down and the other ascends, just as a 2lb. weight would weigh down a 1lb.—*Father:* I see now you understand a little when and how the natural current is produced in mines.

Son: Yes; and I understand also when it is not.—*Father:* Do you? Be not so confident, my lad. Remember, I have been informed there is a pit near Dudley Hill, Yorkshire, in which it was said the natural current continued without ceasing for 18 months.

Son: They may say it was the natural current; but I see the subject now so clearly, that it is impossible to make me believe it, unless I knew there had been no hot days during the summer months on which it had taken place, because the hot air on the surface is in summer many degrees higher than the hot air in the up-cast shaft when no furnace is at work; consequently, it

becomes much lighter in weight, and cannot weigh down the other when it enters in the down-cast scale; and it being balanced, there is a standstill, or no natural ventilating current.—*Father:* I am glad your views on the subject are the same as mine; yet I have several more statements to make on the natural ventilation of coal mines.

Son: You say when the air is made hot, it expands, and thus each cubic foot of air becomes lighter as the temperature increases. Do you know the weight of a cubic foot of air at temperatures varying from 32 degrees to 222 degrees?—*Father:* See, I have a table here. By it you may find the difference in the weight of a cubic foot of air from a temperature of 32 to 222 degrees.

SHOWING THE EXPANSION OF THE HEATED AIR, AND ITS WEIGHT.

Degrees of Heat.	Weight of a Cubic Foot in Grains.	Volume.
32	550	100
42	539	102
52	529	104
62	518	106
72	506	109
82	495	111
92	487	113
102	479	115
112	470	117
122	461	119
132	453	121
142	446	123
152	439	125
162	432	127
172	426	129
182	420	131
192	413	133

202	....	407	.....	135
212	.....	401	.....	137
222	.....	394	.....	139

Therefore, suppose you have a pitful of air, at a temperature of say 32 degrees, and one at 62 degrees, you may find by the table the difference in weight of the two.

Son: Suppose two shafts are equal in depth and area, each say 800 yards deep, and 158 square feet in area, one shaft the down-cast, and the other the up-cast, the temperature of the air in the down-cast is 42 degrees, and in the up-cast is 62 degrees. Do you know what weight of air there will be in one shaft more than in the other? *Father:* You may soon find the difference in the weight of the two. All you have to do is to get a knowledge of the table, and make your calculations accordingly.

Son: If, then, the temperature on the surface raised the air in the down-cast to the same temperature as that in the up-cast (produced by the natural heat of the mine), that is, to 62 degrees, would there not be the same weight of air in the one shaft as in the other? And if so, by the same natural laws, if the heat on the surface in summer raised the temperature of the air in the down-cast 20 degrees above the natural heat in the up-cast, one being at 82 degrees, and the other only at 62 degrees, would not the air which filled the down-cast scale weigh less than the air in the up-cast scale?—*Father:* Just so, but it could not propel air down into a mine and through the workings with the temperature of the air so much higher in the down-cast than in the up-cast. No ventilation could take place unless the air was propelled by another power. For your better information I will give you another table, to enable you to find the difference in the weight of air in proportion to the difference in temperature. Here it is:—

Table of the Pressure of the Air,

In lbs. avoirdupois per square foot of surface of area of shafts of different depths, and subjected to different degrees of temperature.

DEPTH OF SHAFTS, IN FEET.

Temperature.	120	180	240	300	360	420	480	540	600	660	720	780	840	900	960	1020	1080	1140	1200
deg.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
32	9.710	14.565	19.421	24.276	29.131	33.986	38.842	43.697	48.552	53.407	58.262	63.118	67.973	72.828	77.683	82.538	87.394	92.249	97.104
40	9.555	14.332	19.109	23.887	28.664	33.442	38.219	42.996	47.774	52.551	57.328	62.106	66.883	71.661	76.438	81.215	85.993	90.770	95.548
50	9.367	14.051	18.734	23.417	28.101	32.784	37.468	42.152	46.835	51.519	56.202	60.886	65.569	70.252	74.936	79.620	84.303	88.987	93.670
60	9.187	13.780	18.373	22.960	27.560	32.153	36.746	41.339	45.933	50.526	55.119	59.712	64.306	68.899	73.492	78.085	82.679	87.272	91.865
70	9.013	13.519	18.026	22.532	27.039	31.545	36.051	40.558	45.064	49.571	54.077	58.584	63.090	67.597	72.103	76.609	81.116	85.622	90.129
80	8.846	13.268	17.691	22.114	26.537	30.960	35.383	39.806	44.228	48.656	53.074	57.497	61.920	66.343	70.765	75.188	79.611	84.034	88.457
90	8.684	13.027	17.369	21.711	26.054	30.396	34.738	39.080	43.423	47.765	52.107	56.449	60.792	65.134	69.476	73.818	78.161	82.503	86.845
100	8.529	12.794	17.058	21.325	25.587	29.852	34.117	38.381	42.646	46 911	51.175	55.440	59.704	63.969	68.233	72.498	76.763	81.027	85.292
110	8.379	12.569	16.758	20.948	25.138	29.327	33.517	37.707	41.896	46.086	50.276	54.465	58.655	62.845	67.034	71.224	75.414	79.603	83.793
120	8.235	12.532	16.469	20.526	24.704	28.821	32.938	37.055	41.173	45.290	49.407	53.525	57.642	61.759	65.877	69.994	74.111	78.228	82.346
130	8.095	12.142	16.189	20.237	24.284	28.332	32.379	36.426	40.474	44.521	48.569	52.616	56.663	60.711	64.758	68.805	72.853	76.900	80.948
140	7.959	11.939	15.919	19.899	23.879	27.859	31.838	35.818	39.798	43.778	47.758	51.738	55.717	59.697	63.677	67.567	71.637	75.616	79.596
150	7.829	11.743	15.658	19.572	23.487	27.401	31.316	35.230	39.145	43.059	46.973	50.888	54.802	58.717	62.631	66.546	70.460	74.375	78.289
160	7.702	11.554	15.405	19.256	23.107	26.958	30.810	34.661	38.512	42.363	46.215	50.066	53.917	57.768	61.619	65.471	69.322	73.173	77.024
170	7.580	11.370	15.160	18.950	22.740	26.530	30.320	34.110	37.900	41.690	45.480	49.270	53.060	56.850	60.640	64.430	68.220	72.010	75.800
180	7.461	11.192	14.923	18.653	22.384	26.115	29.845	33.576	37.307	41.037	44.768	48.499	52.229	55.960	59.690	63.421	67.152	70 882	74.614
190	7.346	11.020	14.693	18.366	22.039	25.712	29.386	33.059	36.732	40.405	44.078	47.752	51.425	55.098	58.771	62.444	66.117	69.791	73.464
200	7.235	10.852	14.470	18.087	21.705	25.322	28.940	32.567	36.175	39.792	43.410	47.027	50.645	54.262	57.879	61.497	65.114	68.732	72.349
210	7.127	10.690	14.253	17.817	21.380	24.944	28.707	32.070	35.634	39.197	42.761	46.324	49.887	53.451	57.014	60.577	64.141	67.704	71.268
212	7.106	10.658	14.211	17.764	21.317	24.869	28.422	31.975	35.527	39.080	42.633	46.186	49.739	53.291	56.844	60.397	63.949	67.503	71.055

This valuable table is by Mr. Fairley's colliery manager. If you wish to know the weight of air in a shaft of a certain depth and temperature, all you have to do is to multiply the area of the shaft by the number of lbs., and strike off the three decimal figures on the right hand of the result, and the remainder will be the total weight of air in lbs.

Son: Are there several powers to propel air down into a mine; and, if so, what are the other powers?—*Father:* The powers are numerous. There is the mechanical power; water-falls in the down-cast; and there are also hoppers constructed at the top of the down-cast, into which the force of the air on the surface blows, and this also may be called a power to propel air.

Son: Do you know what quantity of air has being produced by the natural heat of the mine?—*Father:* I can give you a little information on that. Some years ago, in Yorkshire, I had two collieries under my charge. We had only two pits at one colliery, a down-cast and an up-cast. We had no ventilating furnace, neither had we any explosive gas, but only carbonic acid gas. In winter, when the temperature on the surface was low and extremely cold, the force of the ventilating currents was so strong as to blow out naked lights. As summer advanced, and the temperature on the surface rose, the force of the ventilating current diminished accordingly, until it ceased to exist; then a fire had to be fixed in the up-cast. The above method was in use not only for eighteen months, but for six years.

Son: Can you show any more collieries where a large natural current was produced?—*Father:* Yes. At the Tyne Main Colliery the natural heat of the mine produced a natural current of 34,955 cubic feet of air per minute. The temperature in the up-cast, caused by the heat of the mine, was 20 degrees above

that in the down-cast. After this the furnace was put to work; then the temperature in the up-cast rose to 94 degrees above that in the down-cast. And so, accordingly, the extra heat from the furnace increased the ventilating current to 101,876 cubic feet per minute. The depth of the up-cast was 280 yards, and the area 59 square feet.

Son: Can you name any more collieries where the natural draught was known?—*Father:* Yes; you have often, no doubt, heard of the Hetton Colliery.

Son: Hetton Colliery! Yes, very often. Some say there never was produced at Hetton the quantity of air as stated by them.—*Father:* But it would be well to know the capabilities of the colliery to produce the quantity. The up-cast pit is 300 yards deep, 153 square feet in area, and is provided with three powerful ventilating furnaces; and to my knowledge, they once had 16 separate divisions of air. Gentlemen disinterested in the colliery have often made experiments, and they say that more than 190,000 cubic feet of air were produced per minute. It would not profit them to say so if it were otherwise.

Son: When experiments were made by them, did they name the quantity of air produced by the natural current, and also the amount of air added to it by furnace power?—*Father:* I stated, before, that at this colliery an increase of temperature of 28 degrees had been produced by the heat of the mine—that is, the temperature of the up-cast was 28 degrees above the temperature of the down-cast. Well, this natural heat of the mine produced 127,145 cubic feet of air per minute. Then the furnace was put to work, and the difference of temperature between the two shafts rose to 86 degrees. This raised the ventilating current to 208,466 cubic feet per minute. This will show that, in this case,

furnace power only added to the natural current 81,321 cubic feet per minute.

Son: I think that the quantity of air produced by the natural heat of the mine was very large.—*Father:* I think so, too. Yet natural ventilation cannot be depended on. Others are of the same opinion.

Son: Have you any more remarks to make on the Hetton Colliery, or on any others?—*Father:* I might name several more; yet what I have said is, I think, sufficient on that subject. But, that you may have another opinion besides mine, I will quote what was stated at Manchester by the late J. J. Atkinson, Esq., Inspector of Mines.

Son: What did he say?—*Father:* He said, "In order to find the ventilating pressure, and the power arising from the use of a ventilating furnace, we require to know the weight of a cubic foot of air at different temperatures, and under different pressures. Careful experiments show that 459 cubic feet of air at 0°, or zero of Fahrenheit, the common thermometer, weigh 39·76lbs., when the pressure is 30 inches of mercury of the density due to 32°—a pressure equal to nearly 14¾lbs. per square inch, which is the ordinary pressure of the atmosphere; but it only weighs 1-30th of this, or 1·3253lbs. when the pressure is only one inch of mercury; and since 459 feet of air at 0° expand exactly a cubic foot for each degree of heat added, we get the following *rule* to find the weight of a cubic foot of air at any temperature and under any pressure:

$$W = \frac{1{\cdot}3253 \times I}{459 + t}$$

Where I = the height in inches indicated by the barometer, and

t = the temperature by Fahrenheit's thermometer. At 88°, under a pressure of 80 inches of mercury, 100 cubic feet of air weigh just 8lbs.; a box five feet square and five feet deep would just contain 10lbs. of such air." On one occasion, at Hetton Colliery, when 225,176 cubic feet of air per minute were circulating, the average temperature of the air in the down-cast shaft was 48½°, and that of the air in the up-cast shaft was 211°. Now by the rule given (if we take the barometer half-way down the shaft to have shown a pressure of 80½ inches of mercury), the weight of a cubic foot of air, taking the average in the down-cast shaft, would be ·08044lb.; and the pit being 900 feet deep, this air would produce a pressure of ·08044 × 900 = 72·396lbs. on each square foot by its mere weight. The air in the up-cast shaft, owing to its being hotter, would be lighter, and only produce a pressure on each foot = 54·297lbs.; and hence the difference of pressure on each square foot of area, between the two columns of air, would be 18·099lbs. Now to find the horses' power producing ventilation, we require to multiply this difference of pressure of 18·099lbs. on the square foot, by the number of cubic feet of air circulating per minute; and then to divide the result by 33,000, the number of pounds raised one foot high per minute by a horse power. In this case, then, we find the ventilating power at Hetton Colliery must have been:

$$\frac{\text{lbs.} \quad \text{c. ft. pr. min.}}{18{\cdot}099 \times 225{,}176} = 123\tfrac{1}{2} \text{ horse-power.}$$
$$33{,}000$$

225,176 cubic feet of air per minute baing in circulation at the time. Some part of the extra heat of the air in the up-cast

over that in the down-cast shaft would have arisen from the heat of the mine, and would cause what is called a natural ventilation, even if furnaces had not been used. But natural ventilation, said Mr. Atkinson, is generally very small in amount, and cannot be depended upon, as in hot weather the down-cast column of air is little or no cooler or denser than the air in the up-cast, and, by making the weight or pressure of the two air columns equal, is liable to stop all ventilation. There is, my son, much valuable information to be had from mine inspectors, if miners would read their lectures and reports; but many choose to remain in ignorance.

Son: I see Mr. Atkinson is also of opinion that there is little or no natural current in hot weather, and that the difference of pressure on each square foot of area between the down-cast and the up-cast at Hetton Colliery, with the large temperature in the up-cast of 211°, was nearly 18·099lbs. I wish to know how to find in this case the total weight of air in the down-cast over that in the up-cast.—*Father:* All you have to do is to multiply 18·099 by the area of the pit, which is 153 feet, and strike off the three decimal figures on the right hand of the result, and the remainder shows how much more in pounds the weight of the air in the down-cast is than that in the up-cast.

Son: How wonderful are Nature's laws; and do not such laws show how wise He is who made them? I should like to have a little information on the propelling force of air in mines.—*Father:* What do you wish to know of the force of the air?

Son: Can you tell what force the air would have on one square foot, at a velocity of from one mile per hour to say 40 miles per hour, and also the number of cubic feet of air passing

per minute, through one foot area at the said velocity ?—*Father :* I had better give you the table. Here it is—

Velocity in miles per hour.	Number of cubic feet of air passing through 1 ft. area per minute.	The propelling force of the air one 1 sq. foot in lbs.		
		lbs.	oz.	drs.
1	88	0	0	1¼
2	176	0	0	5
3	264	0	0	11
4	352	0	1	4¼
5	440	0	1	15½
6	528	0	2	14
7	616	0	3	15
8	704	0	5	1
9	792	0	6	7½
10	880	0	7	14
11	968	0	9	9
12	1056	0	11	8
13	1144	0	13	8
14	1232	0	15	12
15	1320	1	1	13
16	1408	1	4	4
17	1496	1	7	4
18	1584	1	9	14
19	1672	1	12	11
20	1760	1	15	8
21	1848	2	2	14
22	1936	2	6	4
23	2024	2	9	10
24	2112	2	14	0
25	2200	3	2	0
26	2288	3	6	0
27	2376	3	10	1

28	2464	3	14	0
29	2552	4	2	5
30	2640	4	6	10
31	2728	4	11	13
32	2816	5	1	0
33	2904	5	7	1
34	2992	5	13	3
35	3080	6	3	5
36	3168	6	8	8
37	3256	6	13	14
38	3344	7	2	12
39	3432	7	8	5½
40	3520	7	14	0

At a velocity of 24 miles per hour, 2,112 cubic feet of air, you see, pass per minute through one foot area at a pressure or force of 2lbs. 14oz. on one square foot.

Son: Do you know at what velocity air travelled at some of the collieries?—*Father:* Yes; at the Cannel Pit, Ince Hall, Wigan, its velocity by furnace power up the shaft was 1,303 feet per minute, or nearly 15 miles per hour. The velocity of the air at Hetton Colliery, when 225,176 cubic feet of air were produced, was nearly 1,472 feet per minute, or nearly 17 miles per hour.

Son: The reason I want to know is this: If a ventilating engine should propel air at a velocity of 17 miles per hour, will the current suddenly stop or come to a standstill the moment the engine stops?—*Father:* No; the current would continue after the stoppage, until brought to a standstill by friction in its route. There is a force from the air (similar to the force in a fly wheel) when in motion. If the fly wheel could be detached from the engine it would continue to revolve until the force in it

was reduced by friction, and it was brought to standstill. When I say that the current of air would continue after the stoppage, I wish you to understand that the fan would have to be constructed so that it could be disconnected in the event of an accident, so as not to obstruct the passage of the air, or otherwise the current would stop at the moment the engine stopped.

Son: I wish to know how long the current would continue after the engine stopped working?—*Father:* As you do not know the density of air, its propelling force, nor the amount of friction to be overcome, you cannot know how long it would continue.

Son: If the engine or fan could be so constructed as not to stop the force of the ventilating current, would there not then be sufficient time to get out the men before an explosion of the gases accumulating in the workings would be likely to take place?—*Father:* It is my opinon there would be time, if so constructed.

Son: I think, father, I have a good knowledge now, how mines discharge gases. I shall be glad to know how mines are ventilated, and also the best way to prevent loss of life; as there is often great loss of life caused by explosions, through not ventilating properly.—*Father:* I will give you a knowledge of the *best* way, and what I say I know no one can contradict. Explosions there are, and I fear always will be, and also loss of life, but such great loss of life can be prevented by a proper mode of ventilation.

How Air is propelled down, through, and around the Workings of a Mine.

Son: Are not mines ventilated by a large furnace at the bottom of the up-cast shaft?—*Father:* Yes; but there are also the steam-jet, the bellows, and the fan employed for ventilating mines.

Son: Well, but they do not, I presume, draw or pull air through the workings of a mine like a furnace does?—*Father:* Air is not drawn nor pulled through the workings by the furnace.

Son: Miners often say, the larger the furnace, the more air will it *pull* through the holes and places nearest the up-cast.—*Father:* I know miners often say and think so; they know no better.

Son: If air is neither drawn nor pulled, how is it caused to pass through the workings?—*Father:* Heat, you know, makes almost everything expand, cold air expands very much by heat; therefore, the furnace produces ventilation by making air hot at the bottom of the up-cast.

Son: Then, when air expands, does it become lighter in proportion to its bulk than cold air?—*Father:* Yes. If one foot of cold air expands by heat into two feet, the two feet, you know, will only weigh the same as one foot did.

Son: Then heat makes air so light that it rushes like a balloon up the up-cast and out of a mine?—*Father:* Yes; and with the air rushing up one shaft, the great weight of air in the other is too heavy to remain in its place; therefore, it falls down or rushes forward to occupy the place of the hot air.

Son: I see; a furnace is like a pump emptying two shafts filled with water—as the water is pumped out of one shaft it receives a fresh supply, which rushes in from the other, owing to its great weight, to occupy the place of that pumped out.—*Father:* Yes; if the workings and the two shafts were full to the surface with water, the water nearest the bottom would be pressed upon by the whole weight of that above it, and the water in the workings between the shafts would be pressed upon by the water from each shaft with the same force. And it would remain stagnant or motionless, unless an outlet was made for it, because the pressure in one shaft would be equal to that in the other. So in like manner will *air* press towards the up-cast as the weight of air in the up-cast diminishes.

Son: Air is not pulled, then, as miners often say, like something pulled or drawn with a rope, but is pressed into the up-cast by the great weight of cold air in the down-cast. But how does a steam-jet, bellows, or a fan ventilate mines, as air is not made hot by them?

Father: You have asked me several questions, all of which I have answered to the best of my ability; I will now ask you a few.—*Son:* I fear I shall not be able to answer your questions.

Father: The questions I require you to answer will be very simple.—*Son:* If so, I will try to answer them.

Father: By way of illustration, then, suppose you have a pair of scales, with a 15lb. weight in one scale, and a 15lb. weight in the other: will the weight of one overbalance or weigh down the other?—*Son:* No. The scales would be at a stand-still, because the weight would be equal in the two.

Father: You are right, my boy, but if you add 1lb. to one of them, making 16lbs. in one and 15lbs. in the other?—*Son:*

That being the case, the 16lb. weight would be sure to weigh down the other.

Father: I see you are able to answer my questions; but again, suppose you take off 1lb., making 15lbs. in one and 14lbs. in the other?—*Son:* The 15lbs. weight would weigh down the 14lbs. the same as the 16lbs. weighed down the 15lbs.

Father: Very well. Now by this I wish you to understand that the atmosphere presses with a weight of 15lbs. into and upon the top of the up-cast as well as into and upon the top of the down-cast, and as one 15lbs. will not overbalance another, but remain at a standstill, so, in like manner, air in mines will not move with an atmospheric weight of 15lbs. pressing at the top of each shaft, unless the weight is diminished or increased at either one or the other. That is to say, all that is required to cause air to pass down one shaft and up another, is either to increase or diminish the weight of the atmosphere at either the one or the other shaft.

Son: Will the steam-jet, bellows, and fan diminish or increase the atmospheric weight at the top of either shaft?—*Father:* They will increase the pressure by forcing air in at the down-cast or diminish it by forcing air out at the up-cast.

Son: How wonderful, father, is ventilation, and yet so clear that if a man cannot see it he is as dark as midnight. But may a steam-jet or fan, &c., be fixed at the top of either shaft?—*Father:* Yes; the amount of air produced for the workings will be just the same, if fixed at one shaft as at the other. You know a pound of pressure, added or diminished, is like the scales—one and the same. Yet the steam, no doubt, would affect the workings if the jet were fixed at the top of the down-cast. In the

steam-jet there are two powers of ventilation. One is its propelling force, the other is the high temperature, therefore it would do more work by fixing it in the up-cast shaft.

Son: I think many persons believe that the same quantity of air cannot be produced by a ventilating engine being fixed at one shaft, as at the other?—*Father:* Some believe the quantities of air produced by both ways would be precisely the same: others say not so.

Son: Much discussion has arisen from time to time, I believe, on this subject?—*Father:* Yes. The subject of propulsion has been the cause of much discussion with men of talent. I, and an eminent viewer (as I was informed he was) near Durham, who signed himself "Miner," spent nineteen weeks' controversy on the same subject.

Son: Indeed; I shall be glad then to have your views on the subject of propulsion?—*Father:* My object, you know, is to give information; therefore you may ask anything on the subject of ventilation.

Son: I wish to ask, would there be any current in mines without motion?—*Father:* No.

Son: With the air being elastic, as you call it, would there be any motion of the current without the density at one end being greater than at the other?—*Father:* No; it would be impossible.

Son: Would there be any increase in the density without additional weight?—*Father:* No; it could not be.

Son: Then additional weight to the current must produce an increased density?—*Father:* Yes.

Son: And that increased density, where there is an open exit, produces motion?—*Father:* Just so.

Son: And that motion of the air, then, is the current produced ?—*Father:* So it is.

Son: Then additional weight to the air, at the down-cast, produces both motion and density at the same time ?—*Father:* Such is the case.

Son: Why is it so ?—*Father:* Because it is a law in nature that one cannot act without the other.

Son: Is it correct, father, that we live at the bottom of a very deep sea ?—*Father:* So it is. The sea is forty-five miles deep. It is not, you know, a sea of water, but a very deep sea of air.

Son: A deep sea of air ! Our coal mines and pits, then, are filled with air just in like manner as they would with water if at the bottom of the ocean ?—*Father:* Just so. All pits and workings are filled and pressed down with air to overflowing.

Son: Pressed down, do you say ? Then the air at the bottom of this deep sea presses upon bodies and substances which lie on its floor, or on the earth's surface ?—*Father:* The weight and density of the air on the surface of the earth is very great.

Son: What am I to understand, father, by the density of the air, for I have often heard of density ?—*Father:* You will understand if two feet of air are pressed into one foot, the one foot is much increased in density, but diminished if one foot of air expands into two feet.

Son: I well understand now when an increased and a diminished density of the air takes place.—*Father:* And you will also understand, no doubt, if two feet of air are pressed into one foot, the one foot will weigh just the same weight as two feet did before, and also if one foot expands into two feet, the one foot of expanded air will weigh one-half only of what it did before.

Son: It is clear enough, father, for any person to under

and they should never forget it. Do you know the weight of air pressing on the surface of the earth ?—*Father:* The average weight of the air pressing on the earth's surface is nearly 15lbs. per square inch.

Son: This atmospheric weight of 15lbs. presses then upon the top of the up-cast, and also upon the top of the down-cast shaft ?—*Father:* It is so, and with a weight such as that is, the density of the air is very great in the workings of a mine.

Son: There is a natural heat in mines ?—*Father:* Yes ; and in some this natural heat is a great ventilating power.

Son: How does the natural heat, father, produce a natural current ?—*Father:* In the following manner : the heat of the mine expands the air, by which it becomes much diminished in density, and therefore much less in weight, so that it rushes up the up-cast.

Son: Is the air obtained, then, from the down-cast, by propulsion ?—*Father:* It is, always, and by this natural heat a great propelling power is produced at the down-cast over that at the up-cast.

Son: How is this power applied in propelling the current through the air-ways from the down-cast to the up-cast ?—*Father:* In the following manner : the least density or weight of the air is always at the up-cast, so that from the first yard the air becomes more and more dense, and the propelling force increases step by step ; every yard in the air-way along its whole route from stage to stage this propelling force increases, until the greatest density and propelling force is obtained at the top of the down-cast ; or in other words, suppose we had two shafts near each other, one the down-cast, the other the up-cast—the length of air-ways from down-cast to up-cast, say 7,000 yards.

At the top of the up-cast shaft a mechanical ventilator is at work, and by its power the pressure of the air is diminished, say one pound. I have no doubt that were it possible to detect the propelling force in every yard of route in the air-way, we should find it to increase uniformly from the first yard of air at the up-cast to the end of the 7,000 yards at the top of the down-cast shaft. The route from up-cast to down-cast being (as we suppose) 7,000 yards, and one imperial pound consisting of 7,000 grains, we should find this propelling force increasing one grain every yard, step by step, until it attained its greatest propelling pressure at the top of the down-cast shaft. In every yard of route this air requires the additional grain of propelling force to overcome the friction of the rubbing surface in its passage, and to move it along. The air then is obtained from the down-cast (you see) by a *propelling* force; not by drawing or pulling from a mechanical power at the up-cast.

Son: I understand now how the natural heat of the mine produces a natural current; but, father, how does the furnace produce currents in mines?—*Father:* Precisely in the same manner as that produced by the natural heat.

Son: How does a ventilating fan employed at the up-cast produce currents in mines?—*Father:* It reduces the weight of the air at the up-cast, and thereby causes the air in the mine to expand, and consequently its weight is diminished in the space occupied.

Son: The air, then, being elastic, a reduction in the weight pressing upon it causes it to expand in the same manner as by heat?—*Father:* They both act in the same manner.

Son: The propelling power increases every yard, then, step by step, along the whole length of the air-way, from

up-cast to down-cast, as shown by the natural heat?—*Father:* The one is precisely the same as the other. I will now suppose that the mechanical ventilator has been removed and set at work at the top of the down-cast shaft. It there exerts a pressure over the atmospheric weight of (say) one pound, which is the true propelling force.

Son: But will it then produce the same quantity of air?—*Father:* Just the same as if employed at the up-cast.

Son: Will the fan have the natural heat of the mine to assist it whether it is fixed at the up-cast or down-cast?—*Father:* Yes, if the air passages rise towards the *up-cast*, but not otherwise.

Son: But how does the fan at the down-cast produce the current?—*Father:* It increases the density or weight of the air in the down-cast shaft, and thus the air in the down-cast becomes heavier than that in the up-cast, and overbalances it, similar to what happens when the fan is at the up-cast, only in this case the difference in weight between the two shafts is caused by an increase of pressure, while in the other it is caused by a decrease. Thus, as I said before, it does not matter whether we add 1lb. to one scale or take 1lb. from the other, for we have a difference of 1lb. either way.

Son: By pressure the air then is increased in density and weight, and also by a fall in the temperature.—*Father:* It is so. If air is produced for the workings of a mine, the density of the air must be much greater at the down-cast, to overbalance the pressure at the up-cast.

Son: Then you would make the density there as much as possible above that at the up-cast?—*Father:* It is the only way to produce a large quantity of air. When you have obtained

the greatest possible density there with the least possible density at the up-cast, you have then obtained the greatest propelling power of ventilation.

Son: A mechanical ventilator may be put to work then either at the one or at the other shaft?—*Father:* It is immaterial where employed: only obtain, I say, the greatest possible density there over the up-cast; for this, and this only, is the greatest propelling power of ventilation.

Son: Will density change in nature if a mechanical ventilator should be employed at the down-cast, to propel air down, because some people say a ventilator will not produce the same quantity of air there, as if at work at the up-cast?—*Father:* Density is density, my lad, all the world over, and it has the same nature too, by whatever power and from what point or place it may be produced.

Son: If density change not in nature, will a mechanical ventilator produce then the same quantity of air by one pound of pressure added at the down-cast, as by a reduction of one pound at the up-cast?—*Father:* The quantity of air produced by each is precisely the same.

Son: You say, father, that the atmospheric weight is 15lbs. per square inch, and this weight presses alike on the top of each shaft.—*Father:* I do.

Son: Then if you add one pound at the down-cast, will it not make 16lbs. there, to overbalance 15lbs. at the up-cast?—*Father:* It will, and by taking off one pound at the up-cast, it will make 14lbs. to be overbalanced by 15lbs.

Son: Will not the air be heavier with a density of 16lbs. pressure, than with a density of 15lbs. pressure?—*Father:* Yes. Its density and weight will be one-fifteenth more.

Son: Yet the propelling force is the same in each case?—*Father:* Just so; the propelling power which moves the current along is precisely the same in each, but not the weight or density of the current nor its velocity.

Son: If the density be one-fifteenth more in one than in the other, and you say the propelling power which moves it along is the same for each, how will the same propelling power move two currents of unequal weights, and yet produce precisely the same quantity of air in one as in the other?—*Father:* Because there is one-fifteenth more air in the same area or space in one than in the other, so that, if the velocity were the same in the two, the largest quantity of air would be produced, you know, by that of the greatest density. So that if 15-horse power will produce a velocity to the current of 16 yards, at a pressure of 15lbs., 16-horse power will produce the same velocity to a current of 16lbs. pressure in the same space of time; the 16lbs. density requiring one additional horse-power, because the air in it is one-fifteenth more than in the 15lbs. density. Also, if the workings and air-ways remain in the same unaltered state, the "work" in the current's motion must be in proportion to the increased and the diminished velocity, its work then must be one-fifteenth more if propelled 16 yards than if propelled only 15 yards. If 16-horse power will propel the current 16 yards, 15-horse power must propel the same current 15 yards in the same space of time, therefore, 15-horse power will propel a current of 16lbs. density 15 yards, and it will also propel a current of 15lbs. density 16 yards, both in the same space of time, and produce in both the same quantity of air. Consequently, a mechanical ventilating power may be employed

either at the down or the up-cast shafts, as the quantity of air produced will be the same in each.

Son: Do you think then that the extra quantity of air obtained by the extra density will be lost by a diminished velocity of the current?—*Father:* The propelling power in this particular case is governed by what may be called the mechanical law of motion. The extra quantity of air obtained by the extra density is lost by a diminished velocity, yet the propelling power being the same in each, the quantity of air obtained in each is precisely the same.

Son: Governed by the mechanical law of motion! I never heard before of currents of air in mines being governed by that law.—*Father:* By this I wish you to understand, if the density be increased to one-fifteenth more, the amount of air in the same area of the air-way will be increased one-fifteenth.

Son: But if increased one-fifteenth, that increased density must, with the same velocity, increase the friction one-fifteenth.—*Father:* Just so. But remember, if its density be increased one-fifteenth, 15 yards of the air-way will contain the same quantity of air in it as 16 yards of the less dense air, so that one current travelling 15 yards and the other 16 yards, in the same space of time, both will produce precisely the same quantity of air and friction.

Son: The quantity of air in each is just the same.—*Father:* And so is the friction alike in each, because if there is a certain amount of friction in travelling 16 yards in a certain space of time, that friction must be diminished one-sixteenth by travelling only 15 yards in the same space of time.

Son: Just so: I see it more clearly now.—*Father:* The extra friction, caused by an increased density, is compensated

for by the friction being diminished with a diminished velocity of the current, so that the quantity of air produced is just the same in each for the same resistance.

Son: It must be so.—*Father:* The "same" quantity of air, mark you (whether increased or diminished in density), will produce in motion precisely the same friction.

Son: I am a little surprised at that information.—*Father:* A given ventilating power will produce the same quantity of air, whether that air be increased or diminished in density, because if an engine is able to produce 16,000 feet of air per minute at a certain density, it will, if the density be increased one-sixteenth, produce a less velocity because the friction is increased, yet the quantity of air produced is still the same, that is 16,000 feet per minute, as there is one-sixteenth more air in the same space. The same is true if the density be decreased as the friction is proportionally decreased, but the engine is then able to go at a greater speed and consequently increases the velocity until the friction is equal to what it was before.

Son: You remember, father, that "Miner" said that any increase of pressure or density at the down-cast is equivalent to a four-fold resistance or friction, while a decrease of pressure at the up-cast is tantamount to a proportionate reduction of such resistance or friction.—*Father:* If "Miner" had informed the public that a reduction of the pressure or density at the up-cast meant not only a reduction of friction, but it meant also a reduction of the "quantity" of air obtained, and *vice versa*, an increased density or pressure at the down-cast meant not an increased friction or resistance only, but it meant also an "increased quantity" of air, and not an increased friction for the same quantity of

air produced—had he said so, he would then have hit the nail on the head.

Son: How does "Miner" make the resistance or friction fourfold with an increased pressure or density at the down-cast?—*Father:* You have asked me, my lad, more than I can answer, unless "Miner" explained himself thus:—If the air travelled not 15 yards, but 30 yards in the same space of time, then friction or resistance will be increased fourfold, and a fourfold expenditure of power will be required to overcome such; then we should have understood what he meant by a fourfold resistance.

Son: But if the current travelled 30 yards in the same space of time as it took to travel 15 yards before, would not a double quantity of air be produced by it?—*Father:* Just so.

Son: Then an increased density at the down-cast will not increase friction for the same quantity of air produced?—*Father:* No, not one iota.

Son: And a decrease of density at the up-cast will not diminish friction for the same quantity of air produced?—*Father:* It will not diminish it one iota. Therefore, one pound of propelling power added at the down-cast will produce precisely the same quantity of air as a reduction of one pound at the up-cast. Why not? Density changes not in nature, but is the same in the two. Friction is the same in each for the same quantity of air produced, and the propelling power is the same, therefore the amount of air obtained must be the same whether fixed at one shaft or at the other. You know, as before stated, that a pound of pressure added or diminshed is like the scales—one and the same.

Son: I am of your opinion; one will produce precisely the same quantity of air as the other.—*Father:* No person is able

to prove otherwise except they have had a ventilating engine at work at the up-cast and removed it to the down-cast, and find that the quantity of air produced by each varies; and then the dip of the mine would have to be considered, as it might also vary the quantity of air produced.

Son: Suppose you had a ventilating fan, at which shaft would you fix it?—*Father:* If possible, I would fix it at the top of the down-cast.

Son: But why; when the same quantity of air is produced at one shaft as well as at the other?—*Father:* I know the quantity of air would be the same, but there would be less danger of filling the workings with explosive gas.

Son: Filling the workings with explosive gas! Why, how can a ventilating fan fill the workings with gas?—*Father:* You know I have stated before, that gas is pressed or pent-up in the strata by the great weight of the atmosphere; therefore, to take away the weight which presses the gas in would let it out, like letting out steam from a boiler, by taking the weight off the valve. Now, in case a ventilating fan were fixed at the top of the up-cast to propel air out of a mine, if the passage in the workings near the down-cast suddenly closed up, every stroke of the fan would empty out that air which pressed in the gas, and thus the mine would suddenly fill with gas, and cause, no doubt, great loss of life.

Son: Do you think it would not fill the workings with gas, if fixed at the top of the down-cast?—*Father:* No; because every stroke of the fan would press more weight upon the pent-up gas, and give a longer time for the men to escape the danger.

Son: You say that ventilating furnaces are fixed in mines that the heat from them may expand the air, and produce a

current through the underground workings?—*Father:* Yes. As a current of air is produced by heat, the more heat you can cause the furnace to produce in the up-cast shaft, the larger will be the quantity of air obtained. A furnace should be fixed in the up-cast where the largest volume of air can be heated by it, as it will produce more air than if fixed in another place; therefore to fix it at the bottom of the shaft is much better than at the top.

Son: Some people think that the top of the shaft is the best place to fix the furnace.—*Father:* If fixed at the top of the shaft much heat would be lost, and you know to have a loss of heat, would be to have a loss of air. When a furnace is fixed at the top of the shaft, all the air in the shaft below the furnace is left unheated; therefore, the larger the volume of the up-cast air you can heat, and the greater will be the pressure of the air from the down-cast. As before stated, heat expands air, and when expanded it is less in weight; therefore, what is required of the furnace is to heat as large a volume of the up-cast air as possible, because, in proportion to the area of the volume of air heated and expanded, the difference in weight between the up-cast and down-cast shafts will be great or small.

Son: I can see now, very clearly. To produce the largest quantity of air for the workings, you must fix the furnace in the up-cast, where it can heat the largest volume of air, for the larger the volume of light air obtained and the greater will be the rush or pressure of air from the down-cast to occupy its place.—*Father:* Just so. Therefore, it is better to fix the furnace at the bottom of the shaft than at the top, however deep the shaft may be, as there is a much larger volume of air made light by fixing it there.

Son: Some people say that if you fix a furnace at the bottom of a very deep shaft, the heated air will become more and more cool as it ascends near the top, and thus becoming more and more dense, until at last it reaches its original condition of coolness, by which its ventilating power becomes diminished or destroyed.—*Father:* The expanding air may contract a little in passing away up the shaft from the furnace to the surface, but there cannot be a larger volume of contracted air above than there would be below the furnace, if it was fixed at the top of the shaft.

Son: I see now. The air, below the furnace to the bottom of the shaft, may be said then to be all contracted; therefore, there would be more cool air by that way than the other. But if the furnace were fixed at the top of the shaft, would not the hot air rush out of the shaft to the surface, with a greater speed than it would if fixed at the bottom, and as the air at the top of the shaft would be much higher in temperature, would it not propel away therefrom the cold air in winter, and by so doing produce a larger current of air for the underground workings?

Father: I will ask you a question or two, which I hope you will try to answer, and which will set you right on this matter. Will not the air heated at the furnace rush away from it to a certain height, with the same velocity, if the furnace be fixed at the bottom of the shaft, as it would if fixed near the top? And if so, will not the air from the workings follow, or rush into the up-cast, with the same velocity, to occupy the place of the hot air?—*Son:* I cannot see that the velocity of the air from the furnace, and the velocity from the workings into the shaft, would not be as great if fixed at the bottom of the shaft as at the top.

Father: Then if the velocity would be as great, it would be much better to fix the furnace at the bottom of the shaft, because there would then be no loss of heat.

Son: Loss of heat? How do you show there would be loss of heat?—*Father:* Fix a furnace near the top of a shaft, and place your hand in the air as it ascends, and you will find the heat will burn you. That heat you feel is lost, but if properly made use of, by the furnace being at the bottom of the shaft, it would change the cold and dense air in the shaft into warm expanded air, and by so doing, increase very much the ventilating volume, just as a balloon, if enlarged by the gas being expanded by heat, would ascend more rapidly, and also overcome a greater weight.

Son: I thank you for the information. I think, with you, that the furnace will do more work if fixed at the bottom of the shaft, and, the deeper the shaft, the better, as in a deep shaft the heat is not lost at the top, before it has been made use of; a larger volume of light air is produced, and consequently, a much larger ventilating current is obtained.—*Father:* You will now remember, that the bottom of the shaft, and not the top of it, is the proper place for a furnace to be fixed to produce the most air.

Son: I do, and it requires, I see, caution and care, and also a person with a good foresight, to prevent loss of life in mines. But I fully expected to have had before this a little conversation how gases are conducted by air through and around the workings of mines.—*Father:* It is my wish to impress on you, and also on every miner in the kingdom, things that will do good for years to come; therefore, as you have a knowledge how air is made to pass down into a mine, we will have a little conversation now, how air is made to pass several ways in and through the workings of a mine.

Son: Will you show how air passed around Lund-hill workings, where 189 lives were lost, and at Risca, and at all those places where great numbers have been lost; and also show a better way to prevent loss of life?—*Father:* Yes, I shall be able to show the mode of ventilation of those places, and also a better way.

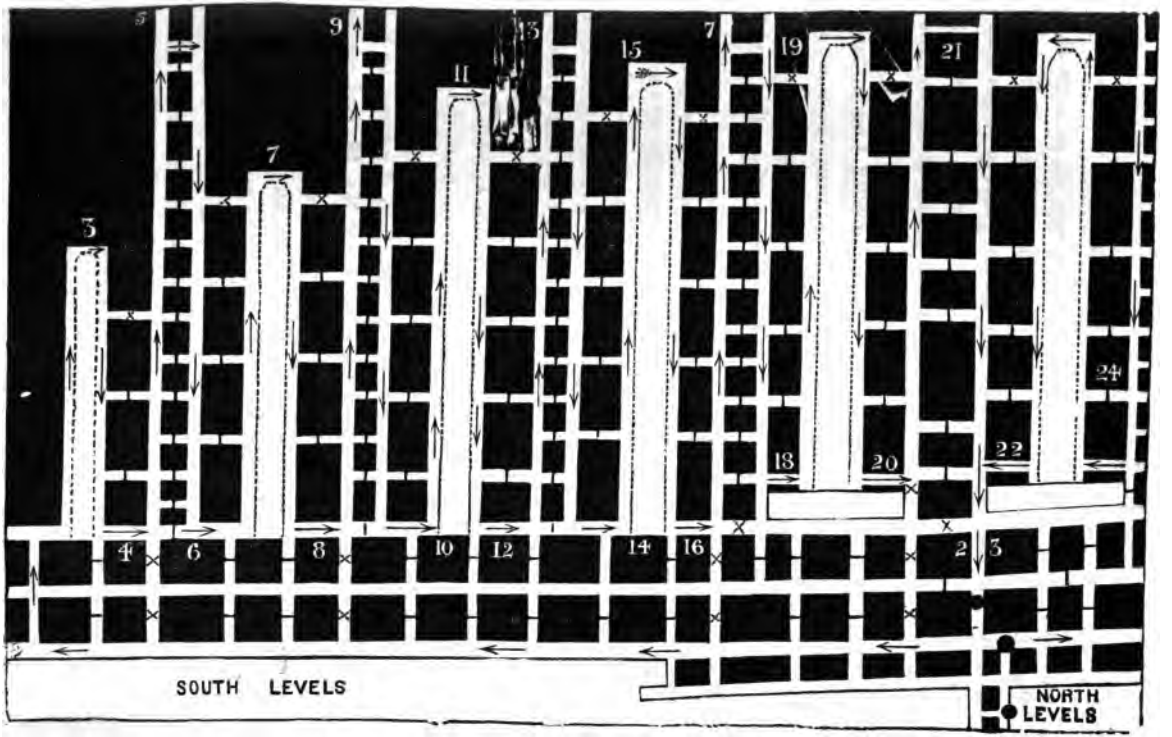
Son: Did you not show the mode of ventilation at Lund-hill which caused the four months' discussion in the public papers—and also a meeting to take place for discussion—between you and the late John Wales, Esq., viewer in the north of England?—*Father:* Yes; poor Mr. Wales, I was sorry to hear of his death. The north people lost a valuable man when he died; he was a man with a good knowledge of mine ventilation. He did not charge me with not showing properly the mode of ventilation at Lund-hill, or the improved mode, but he had a notion I had made an error in the non-fixing of a regulator; and at the end of the discussion it was stated, at the meeting, that Mr. Wales fixed the regulator in the plan *for* the manager, while I *showed* him *where* to fix it.

Several Ways of Ventilating Mines.

Son: You have a plan, I see, showing the ventilation and working of mines. Where is this mode of ventilation adopted?—*Father:* In all mines where great loss of life has been caused by explosions.

Son: Was this way of ventilation in use then at Lund-hill, where one hundred and eighty-nine persons were killed by that dreadful explosion, and also at Risca, where more than one hundred and forty were lost?—*Father:* The plan you see shows the way of ventilation they had on the south levels at Lund-hill;

PLAN No. 1, of Ventilation at Lund-hill before the Explosion.



and the supposed place of the explosion was at or near the No. 24 (see plan); some supposed the place of the explosion to have been at the furnace, where the whole quantity of gas from all the workings passed through, as the power or shock of the explosion spread, and affected north and south at one and the same time.

Son: Were there not many doors at Lund-hill? I understand there is always great danger in mines where many doors are in use?—*Father:* There were 52, just as many as there are weeks in one year. There are always a great number where this mode of ventilation is adopted.

Son: Do the arrows on the plan show the route of the air from the down-cast into and around the workings to the up-cast?—*Father:* Yes. You see the arrows show the passages of the air current; it commences its route at No. 1, from there it travels on the south level to No. 2, from there to No. 3, from there back to No. 4, then onward to No. 5, back again to No. 6, from there onward to one of the working faces at No. 7, then it is conducted back to No. 8, from there to the face of one of the narrow workings at No. 9, it then returns to No. 10, from there to the face of another working place at No. 11, then it returns to No. 12, it then enters the narrow working face at No. 13, and comes back again to No. 14.

Son: Well, father, what a great route air travels by this mode of ventilation.—*Father:* Yes, and if the route extended as far from the down-cast through the workings to the up-cast, as one end of the river Nile is far away from the other, go it must, if only it can travel. There is no alternative with some managers but one continuous route, conducting explosive gases into every part of a mine.

Son: By passing air backwards and forwards into and out of one working place and another, there must be a large quantity of gas collected in the air, long before it discharges itself at the top of the up-cast. The air has yet to travel in and out from No. 14 to Nos. 22 and 23.—*Father:* At No. 22 (see plan) the gases accumulated in the air from all the workings in the north part of the mine meet the adulterated air from the south; at that junction the two currents join. Afterwards this large adulterated current passes through a blazing fire or furnace at No. 23.

Son: Is this way of ventilation of very ancient origin?—*Father:* It was adopted first by our great grandfathers in the early days of coal mining, and, I am sorry to say, handed down from one generation to another, as it exists at the present day.

Son: Is there no improvement to be made for the better and safer working of mines, and, if so, why continue this great life destroyer so long?—*Father:* There are improvements in mine ventilating as well as in all other things, yet I cannot tell why the improvements are not adopted, unless some managers wish not to give up that which was left them by their ancestors; or, their knowledge of mine ventilating may only consist in what was well known in the early days of mining.

Son: If that mode of ventilating is adopted, we may well have great loss of life and property. I fear many lives have been lost by it.—*Father:* Many lost! The number is too great to be told. Your father was left fatherless in the world by it, and, from early life, I have had to make my way through the world without the blessing of a parent's care.

Son: I think, father, there was not so great a number of lives lost by explosions in the early days of coal mining as at the present time by the same mode. Can you tell why there was

not?—*Father:* Because they had only limited means of getting out coal to the surface, they had only a limited number of works, they had only a limited number of persons employed in the works, and only limited means of ventilating them. Therefore, if they had only a limited number of persons, of means, of works, and of air, they had not so much gas in the air at the time of an explosion; that is to say, they had less air, and they had less works for the air to pass around; therefore, they had less explosive gas in the air when it ignited; and if less gas, the power of the explosion would be less when it did take place; and if the explosive power were less, and there was a less number of works, there would be a less number of persons lost at the time of an explosion. Therefore, by the same mode of ventilation, there was not so great a number of persons lost as now.

The Danger of one Way of Ventilation, and the Safety of another.

Son: Air is conducted, you say, from one working place to another, clearing away the gas in its passage, from all places in its route?—*Father:* Some managers adopt that mode for the ventilation of mines (this is clearly shown by the Lund-hill plan), but it is neither safe nor profitable for miner or master.

Son: Why not safe and profitable?—*Father:* Because the mode requires many doors fixing in the tram-gates to send air forward from one working place to another, and to allow waggons to pass and repass with coal from the workings. It is unsafe, because, if one door be left open, all lives would be jeopardised; unsafe, because, if one place be affected, all the miners are in danger; unsafe, because the explosive gas, conducted from all parts of the mine, will make a large quantity when collected; and

therefore, the power of the explosion will be very great when it does take place; unsafe, because an explosion in any one part would affect the whole mine. There is expense, also, in making and keeping air-gates large enough to make the passage of sufficient area to take the gases away from all the separate working places; expense in making a great number of doors; expense in fixing them; expense in opening and closing them to allow waggons to pass and repass; expense in the furnace expenditure of coal, as more friction of the air is caused by propelling a large quantity into and around so many working places; expense in destroying the whole workings if so large a quantity of gas becomes ignited; expense in day-wage work, &c., to make all good after.

Son: If air be conducted, then, from one place to another, it is not safe?—*Father:* No; this may be seen by the mode of ventilation adopted at Lund-hill, all the gases discharged from the strata in the whole mine are collected in the air, as it passes onward from place to place, until the accumulation of gas becomes so great that an awful explosion takes place.

Son: I wish to see, father, a little clearer, as I do not understand it properly.—*Father:* Well, I will try again to make it more clear. Suppose five separate groups of miners are working where much explosive gas is discharged, and each place requires 6,000 feet of air per minute for ventilating purposes. Now, if all the five currents of air make one, and the 30,000 feet pass through all the workings in one continuous route, all the five parts will be affected by an explosion, because all the separate working parts give off gas in the one current in which the explosion takes place, and, as all are ventilated by it, all are affected by the same. Among the first group of miners all the air enters, after which

it leaves that group or place and passes on to the second group, from them to the third, from them it proceeds to the fourth, and lastly to the fifth group. In the first group the men are well ventilated, and may be considered safe, providing that air and gas be not allowed to pass over a burning fire or furnace. In the second group they are less safe, from the fact that all the fire-damp discharged in the first group goes directly in a current upon the second group; then it proceeds to the third, from them it passes on, with the gases accumulated in its passage, to the fourth group; and then onward the adulterated current goes to the fifth group. Who, indeed, does not see that the miners in the fourth and fifth positions are liable at any moment to be destroyed by an explosion of fire damp, unless the greatest caution be exercised? One part of the mine would be filled with raging flames, and the men scorched to death by the burning gases; in another they would be killed instantaneously by the expansion of the hot air and gas, or suffocated by the noxious gases which fill all parts of a mine after an explosion.

Son: There are other ways of ventilating mines, you say, than that adopted at Lund-hill? The mode of ventilation adopted there was to conduct the *whole* current of air around in one continuous passage.—*Father:* Yes, there are other ways of ventilation. The air is conducted by another mode in the following manner:—A portion of the air is conducted pure into one working place; after ventilating this place, and after the current has become impure because of the gases collected in it, a fresh supply of pure air is mixed with it to ventilate another place; and in like manner this mixture of pure and impure air takes place alternately when each working place is ventilated; so that the one air current passes on, with all the gases in the

mine accumulated in it from every working part, until it discharges itself at the top of the up-cast.

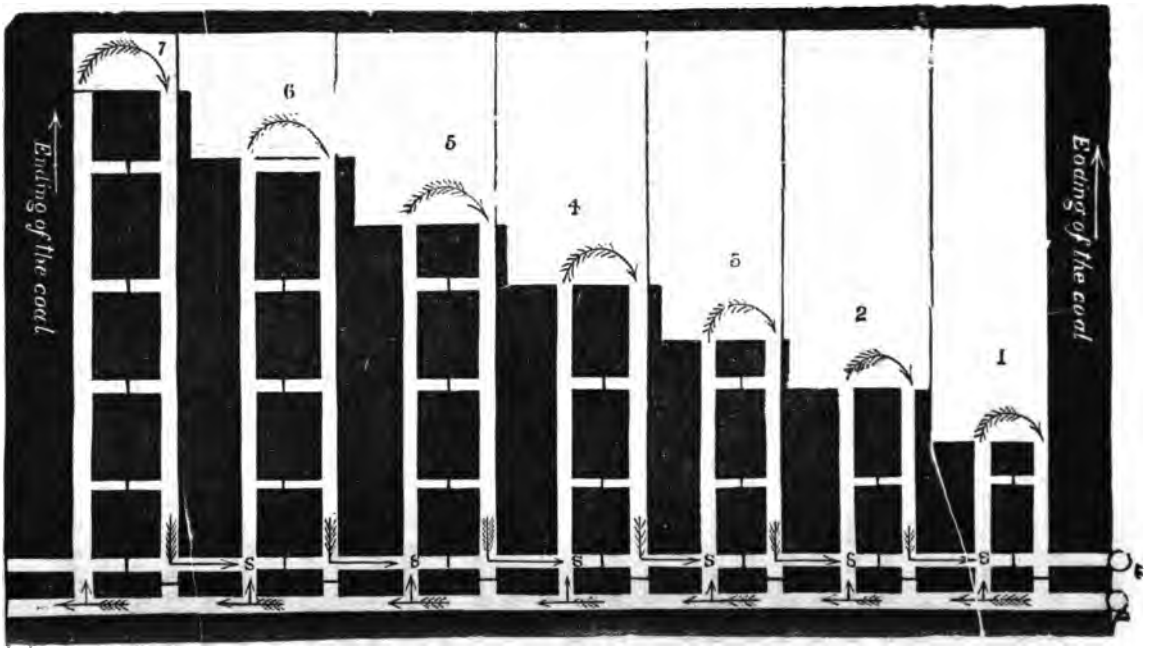
Son: Does plan No. 2 show this mode of ventilation, by which working-places are supplied with a mixture of pure and impure air?—*Father:* Yes. The points of the arrow on the plan show the passage of the air through the workings. When the air first enters at the down-cast, it passes direct to No. 7 working place; after ventilating this place it is supplied with a portion of fresh air for the ventilating of No. 6 working place, the mixture taking place at the letter S (see plan), and in like manner, all the other working parts are ventilated with a mixture of pure and impure air; the mixture takes place for all parts at the letters S S.

Son: Is this mode adopted for the safety of miners?—*Father:* Those persons who adopt such a mode believe it to be for the good and safety of miners, and economy for the employer.

Son: By this mode, air-gates, I see, do not require to be so large as those where the whole quantity of wind passes in one continuous current through the workings, like that at Lund-hill; therefore, the expenditure no doubt will be much less.—*Father:* The mode would be more economical than if the whole of the air passed around the workings in one continuous current; but the danger of loss of life by an explosion would be the same as that of ventilating by one currrent.

Son: It is clear that an air-gate will not require to be so large, for, say 6,000 feet, or 12,000 feet of air to pass, as for 50,000 or 60,000 feet, and, therefore, the expenditure will be much less. But why is the danger of loss of life the same?—*Father:* Because this mode of ventilation neither divides the air nor the gas, the gas is conducted in the same way as before described from one working place to another, in one con-

PLAN No. 2.—The Impure Air supplied with Fresh Air.



tinuous route, so that all the gases in the mine become accumulated into one large quantity; therefore an explosion in any part of the mine would ignite the whole quantity of gas, and thus the power of such an explosion would affect all parts where the air passed, and cause great loss of life.

Son: You say that to cause the air to pass in one continuous current through the workings, a large number of doors are fixed. I wish to know, then, how this mode of supplying the workings with a mixture of pure and impure air is accomplished?—*Father:* By fixing *regulating* doors in the air passages. Air, you know, will always rush by the nearest route from the down-cast to the up-cast, and consequently regulating doors are fixed in the air-passages to prevent the great rush of air going in that direction, a portion of it only is allowed to pass that way, the remainder being sent round the longest routes, which would otherwise be left without air. The doors are fixed in the openings *between* the in-take and return air passages, at or near the letters S S. (See Plan.)

Son: I shall be glad to know, at a future day, why air rushes round the nearest working places, and those workings at a great distance are left destitute of air. But how, father, are regulating doors fixed in mines?—*Father:* They are fixed in those air-passages through which the air rushes with great velocity, in order to take off such quantities of air as are required for other working parts of the mine, and they are so fixed as not to fill the whole space of the air-passage, but open spaces are left to allow a proper quantity of air to pass; thus dividing the air, but not into separate distinct currents.

Son: I see now; but what other ways of ventilation are adopted?—*Father:* Another is, that of conducting the air into

the workings similar to the plan of ventilation adopted by the late John Buddle, Esq., viewer in the North of England.

Son: Was Mr. Buddle's plan considered a safe way of ventilation?—*Father:* I believe it was much thought of in his day; yet it is not a safe mode of ventilation.

Son: What way did he adopt?—*Father:* It was one similar to several I have seen used in mines at this day, which many managers call dividing the air; yet it is not what may be called splitting it into distinct currents. This mode is to divide the air into separate parts, for separate groups of miners; after which, all those separate parts of air return into the same current again from which they separated. Then again, this one current of a mixture of winds is divided a second time for more groups of miners; after this all the separate winds form one again, and this one mixture of wind passes on further into the extremity of the mine, until the said one current requires dividing for other workings of the mine, and so the same is allowed to divide or separate into as many parts as there are workings, returning and forming one current again after being divided. This mode cannot be properly called splitting the air, because it is allowed to return again into the current from which it separated itself, and no working part has a wind separate and distinct from the others, as each division is a mixture of winds from the others, with the gases collected from the same in each wind. Therefore, as the air is allowed to spread in and through the workings, every part would be affected by an explosion; because the gases collected from all parts would be mixed in the said wind in which the explosion might occur. This being the case, the flame of the ignited gas would fly and spread in and through the workings of each part

like the electric fluid, carrying death and destruction in its passage. By this it will be seen that this mode of ventilation does not divide or diminish the explosive power (gas), as the explosive gas would be like a combustible train, and if ignited in any part, would fly through and around all the parts wherein it circulated. Plan No. 3 is, I believe, a representation of Mr. Buddle's mode of ventilation: by an inspection of it, you will see that the air separates ten times in its passage through and around the workings, and the current of air which ventilates the whole mine is formed into one wind as often as it is divided, by which all the gas discharged through the whole mine is collected into one vast quantity. As to the number of times the air is separated in its passage through, from the down-cast to the up-cast, see Plan at Nos. 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10. This mode, if called splitting the air, is not a separate distinct dividing of the gas.

Son: Was this the mode of ventilation you alluded to in your reply to a person in the "Miner's Advocate," who requested you to inform him of the meaning of split winds in mines?—*Father:* This plan does not show the mode of splitting air, yet it is the one I alluded to in my letter.

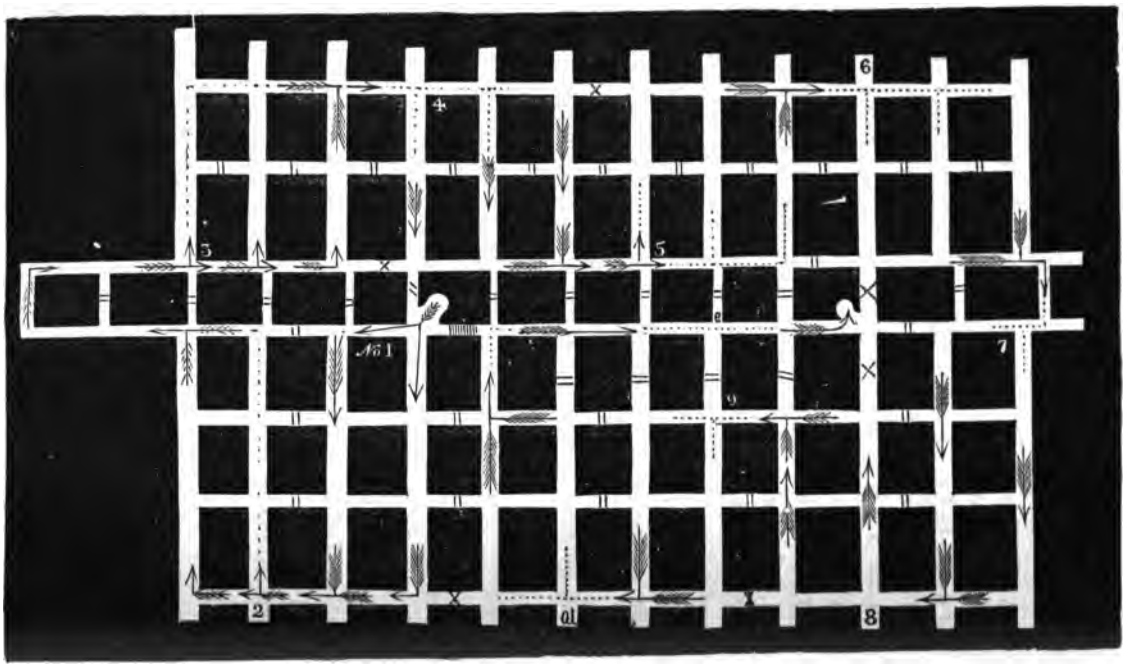
Son: Let me see the letter.—*Father:* Here is the substance of it; it will give you a knowledge between this mode and that of ventilating by separate distinct currents.

THE LETTER.

Sir,—In your "Notices to Correspondents" of last week's impression (January 2), I am requested to inform a "Constant Reader" the meaning of "Splitting" the air.

My object through life has always been (and I hope will, until my work on earth is finished) to try to better, if possible, the miner. When

PLAN No. 8.



I speak of mine ventilation, it is from a practical knowledge of seeing and doing the work, and not from a knowledge only of theory, reading and hearing. When I speak of air splitting, I mean separate, distinct currents, and not that kind of splitting which is similar to that which takes place when the wind blows on the surface against a building, the wind being separated by it, and afterwards mixed again; and so the wind is divided and mixed in passing and repassing every building. The above is similar, I say, to the splitting adopted by some managers. They allow the whole of the air to pass in one large current, until one portion of the air is caused by the friction to pass around one part of the mine, and another portion around another part; and so the same air is allowed to split or divide as it rushes through the mine into as many parts as are working, returning and forming one wind after it has been divided; therefore, it is not a separate, distinct current or wind, but a mixture of winds, with gases collected in them from all parts. This mode, as before stated, divides neither air nor gas properly, as gases from all parts are mixed in the one current; therefore an explosion in one part would affect all. But, I am asked, "What is meant by splitting the air?" I would also ask: What amount of air can be produced for the whole workings of a mine? Can 20,000 feet, 40,000 feet, 60,000 feet, 80,000 feet, or 100,000 feet be produced per minute? Be that amount less or more, do not propel, in one current, the whole of it around the workings of a mine? Divide, split, or separate the whole into "distinct currents," or parts, of say from 5,000 to 7,000 feet of air for each current, after which, if five, ten, fifteen, or twenty miners are getting coal in one district of the mine, supply the said number of miners with one current, say 6,000 feet of pure air direct from the down-cast; after which, conduct this current direct from the said miners to the up-cast, and not ventilate other workings with it afterwards. Supply another current, say 6,000 feet, of pure air to miners working in another part of the mine, conducting this current as before direct from the down-cast to the working parts, and therefrom to the up-cast, and so on in a similar manner supply each party of miners with distinct currents.

If the discharge of explosive gas be too great in the workings for, say, 6,000 cubic feet of air, to dilute and render it harmless, reduce the num-

ber of workings for the amount of air, or make two divisions of the number of works, so that the gas may be divided and rendered harmless by each separate current or division of air—that is, regulate or reduce the number of works to be ventilated in proportion to the quantity of gas discharged in such works. But it may be asked, how or by what way is 5,000 or 7,000 feet of air to be sent or propelled into the workings in separate quantities, as the distances for the air to travel are not equal in length, the distance being much greater around one number of miners than around another; and such being the case, more than 6,000 feet of air may pass into and around one working part, and much less than this amount around another part; by this, one part will have a superabundance and another a deficiency of air. In reply to the above—"Such, doubtless, will be the case if the air-gates be large enough to allow a larger portion of the air to pass into one part than into another." All that is needful in this case is simply to enter the return air-gates of those parts from which a little air is required to be taken, and by fixing a regulator therein, each division of air may be so regulated as to allow only a sufficient quantity for each working part. Again the impure air, in its return, may come in contact with the intake pure air of another division; if so, an overthrow similar to a bridge over a canal, will be required at such place, the overthrow so constructed as not to allow a mixture of the two currents. Ventilate the workings of a mine as above stated, and you will have separate or split winds therein, and no explosions like Risca, Lund-hill, and many more such like.

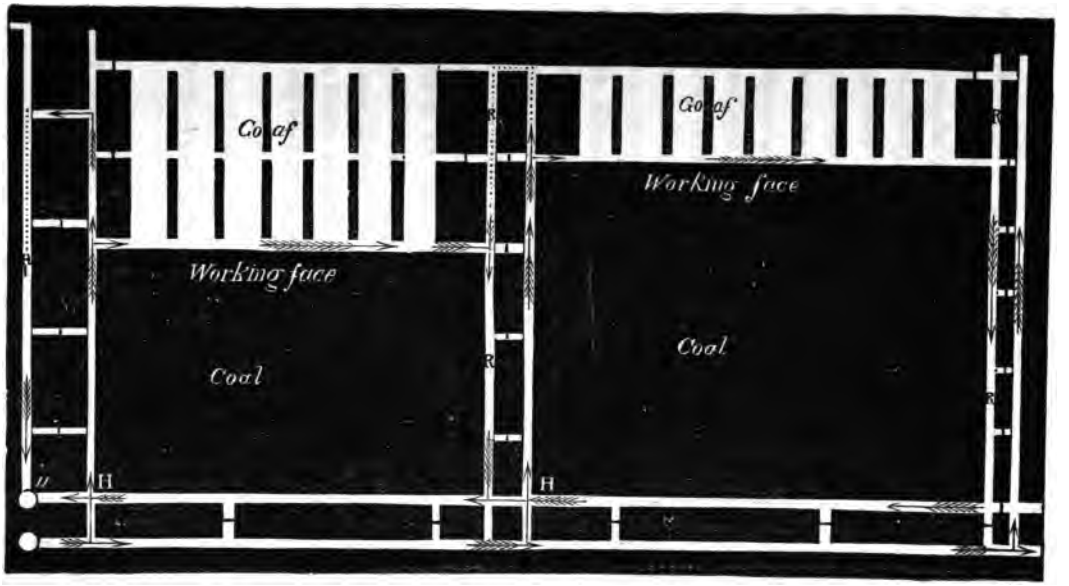
Yours faithfully,

St. Helens, Jan. 11. WM. HOPTON.

Plan No. 4 is a representation of this mode of splitting the air into separate distinct currents, and on some of the other plans which I give you, this way of ventilation is shown.

Son: Then an explosion, as shown in Buddle's plan of ventilation, and also that of Lund-hill, would cause great loss of life, because all the gases accumulated in the air pass from one working place to another in one large quantity?—*Father:* Such is

PLAN No. 4.



certainly the case. The object of ventilation, namely, the preservation of life and property, is altogether lost sight of. The method has always been to send around the workings a large current of air to take a large quantity of gas away; but the object should be to divide this large quantity of gas by ventilating separately for each group of miners the workings where it is discharged. Divide the power (gas), and the effect produced by an explosion would be very little. If you had to work in a room where a ton or barrel of gunpowder was exposed to a great number of people, and at any moment an explosion might take place, you would say, remove that large quantity of gunpowder, or divide it into pounds, so that the whole may not explode if one part of it should become ignited.

Son: I see the reason, now, why people often say after an explosion of fire-damp, that such and such a mine, where great loss of life has been caused, was well ventilated; it is because there was a large current of impure air.—*Father:* No mine ventilated with impure air can be called a well ventilated one, if the air passing through be ever so great. I do not doubt for a moment that, where great loss of life and property was caused, they have had much air, but it was impure. No one will doubt that, because the explosion which caused the loss of life is a witness, as an explosion cannot take place in air where gas is rendered harmless.

How the Power of an Explosion may be diminished.

Son: The best mode of ventilating mines, then, for the safety of miners, is to split the air into parts, by which each group of miners is supplied separately with their own pure air

direct from the down-cast?—*Father:* Yes, pure air is split to allow each working part its own proportionate quantity, in proportion to the accumulation of gases discharged in each part.

Son: I see, father, on plan No. 4, several letters, R and H; what am I to understand by them?—*Father:* An overthrow is fixed in those places where you see an H, and a regulator at R. An overthrow is fixed so as to prevent a mixture of pure and impure air, and is so constructed that one current can cross over the other. Regulators are also fixed to supply each separate working-place with its own quantity of air, in proportion to the accumulation of gas; if no regulators were fixed, one part would receive (in proportion to the distance) more air than another.

Son: Then explosive gas by this mode is prevented from accumulating in large quntities?—*Father:* Just so; that is the object of splitting the air. If one wind pass around, say, four working parts, explosive gas will accumulate in the air, from all the four parts, so that four times as much gas will be in the current as there would be if only one-fourth of the air ventilated one place only. In proportion to the quantity of gas ignited, so is the power of an explosion.

Son: Then what you wish me and others to understand is this: if one hundred feet of gas per minute accumulated in each working part or group of miners, you would not ventilate four parts with one great current of air, as by so doing you would have four hundred feet of gas in it; but you would ventilate each group of miners separately, because then you have only one hundred feet of gas to explode, and not four hundred feet; and by reducing the gas to one fourth, the explosive power is reduced four-fold.—*Father:* Such would certainly be the case. If loss of life and property is to be prevented, splitting the air

for the ventilation of mines must be adopted, because great loss of life is caused by igniting too large a quantity of gas. Split the air for the workings into portions, and you divide the great explosive power (gas) with the air. Take the gas away, and you take that power away which causes such loss of life.

Son: Then if the workings of four groups of miners are ventilated separately, and gas ignites in one, you prevent the explosion spreading to the gas in the other three groups, and therefore prevent loss of life; and you also reduce the explosive power in that part where gas explodes by three fourths.—*Father:* By splitting the air, several objects are accomplished, by which loss of life and property is prevented. 1.—The explosive power is reduced to one-fourth of what it would be if one large current of air ventilated all the four parts; and by the power being so reduced, the men may escape even from the exploded part without loss of life. 2.—As the explosion is confined to the one particular part where the gas ignites, you prevent loss of life in all the other three parts, because no explosion takes place in them, as in no part of the route of the explosive power can it communicate with the other three. 3.—The quantity of choke-damp produced by an explosion is reduced by this mode of ventilation to one-fourth. You know in proportion to the quantity of explosive gas ignited, so is the quantity of choke-damp after an explosion; therefore, when the quantity of choke-damp (which destroys the life of the miner) is diminished, the loss of life is diminished accordingly. 4.—The danger to a person's life is reduced fourfold, because the lives of those employed in other parts are not jeopardised by working in the air which has passed around other places. 5.—This mode prevents doors being blown away, because few are

required, and the power which blows them away is reduced, therefore the danger of loss of life in consequence is reduced. 6.—This mode supplies every working part direct from the down-cast with pure air, therefore, when an explosion takes place, the fresh air enters the exploded part shortly after, and thus loss of life is often prevented. But such is not the case by the other mode of ventilation; for lives are lost for the want of fresh air after an explosion.

Son: Is there anything said against splitting the air?—*Father:* Yes, much is said against it, and that, too, by men professing to have an extensive knowledge of mining.

Son: What is said?—*Father:* They say if one wind does not ventilate all the four working parts, you diminish the quality of all the parts by ventilating each separately, and, by so doing, you may not have a sufficiency of air for each part.

Son: Well, but they should remember also that if the three divisions of air do not pass around the fourth working-place, the gases discharged in the three divisions do not pass into it, and therefore, if you take air from this part, you also prevent gas from going to it. And there is more danger in not having a sufficiency of air to take a large quantity of gas from a number of works, than not having a sufficiency of air for a less quantity of gas. There was sent through the workings at Lund-hill a large current of air to take a great quantity of gas from many parts, but the large current was not sufficient for the quantity of gas, and awful was the result. At Burradon, Risca, Cymmer, the Oaks Collieries, &c., a large current was also sent through the mine to take a large quantity of gas from many parts; but the current of air was not sufficient, and the result was accordingly. If gases discharged

in the workings of one group of miners cannot be rendered harmless by a certain quantity of air, gases discharged in the workings of four groups of miners will not be rendered harmless by four times that amount of air. Therefore, as no one can show great loss of life by splitting, it is better to adopt that mode for the safety of miners.—*Father:* I think you will be able to show the public shortly the best mode of ventilation. Yet some men recommend for the safety of miners, stoppings, doors, and overthrows to be strong enough to withstand the shock or power of an explosion, because stoppings several feet thick are blown away by the power.

Son: I think it is very strange, father, for those professing to have much knowledge of mining, to talk in such a way. Divide, reduce, or diminish that power which blows the stoppings away, and you prevent miners from being blown away. It is of little use making stoppings, &c., to withstand a greater shock, if a miner's body is not able to withstand it. If such people were in a mine when an explosion takes place (if spared to get out), they would say—"Unless this power be reduced, I will not go down here again." But, father, how is this mode of splitting the air and gas accomplished, by which every working part of a mine may be supplied direct from the down-cast with pure air?—*Father:* By fixing regulators and overthrows in a mine. Overthrows are similar to a bridge over a canal, which passengers go over, and vessels pass under. As the air passes pure from the down-cast into the workings of one division of miners, it may come in contact with the return impure air of another division; and, as the impure air is required to cross or go over the pure, an overthrow is required at such a place, to cause one division of air to cross over the other—such crossings are so constructed

as to prevent a mixture of the two currents. Regulators are also fixed in the nearest return air-gates to the up-cast shaft, to regulate the proper quantity of pure air in proportion to the gases discharged in each part, and thus one group of miners, with a deficiency of air, will be supplied with a sufficient quantity, or a little will be taken from those parts which have a superabundance.

Son: You say the mode of ventilating mines by splitting the air into separate distinct currents is much better both for the safety of miners and economy of employers. I shall be glad to know, father, why it is not adopted. Is it because people think mines will give off more gas by this mode of ventilation?—*Father:* No; a change in the mode of ventilation will not cause an extra quantity of gas to be discharged in mines, as the discharge is the same for one mode as for another.

Son: Yet people who have not a proper knowledge of mine ventilation may think there is less room in the air-passages by the mode of splitting into separate distinct currents, than there would be if all the divisions of wind formed one, and passed in one current the whole quantity of air through one air-gate, and this may be their objection.—*Father:* If many divisions of air form one large current, and pass in one continuous route through one air-gate, room will be required in the passages accordingly, or the same quantity of air cannot be produced by one mode of ventilation as by the other; therefore, as there is more room for the air (in the passage) for separate divisions than for one large current, it cannot be the cause why such is not adopted.

Son: Is the production of pure air for the workings much less by this mode of ventilation, and is that the cause why it is not adopted?—*Father:* No, because by this mode you produce a

much *larger* quantity of air; yet all the air will not be sent through the workings in one large current, but will be distributed in quantities in proportion to the discharge of gas in each working part, and there will not be, as I have shown, a large mixture of impure air. This extra quantity of pure air is obtained by diminishing the friction, and by allowing more space in the air passages.

Son: Some may have a notion, father, that if one large current of air ventilates—say six divisions of miners, one-sixth part of that current cannot ventilate or do one-sixth part of the work as well as all the air does all the work?—*Father:* That cannot be the objection, because one-sixth part of the air will do one-sixth part of the work much better; for the impure air by this mode is conducted away to the up-cast, and not mixed with the pure air to occupy its room in the air-passage, and impede its progress through the workings by taking up the space it ought to have.

Son: If one large current of air ventilates, say six divisions of miners, and is, after ventilating the workings, very impure with gases, do you think that is the cause why splitting of air is not adopted?—*Father:* No, that cannot be the cause; as the quantity of gases conducted in and around the workings is much less by this mode of splitting than by others. Nearly one-half of the gas discharged in the mine does not enter the workings, but is conducted away to the up-cast. By the old mode of ventilation, the gases discharged in the return air passages of one part pass into the workings of another part, but not so by the new mode. If a mine cannot be worked with safety by the mode of splitting, it cannot be worked with safety by ventilating many divisions of miners by one large current; because, if there is

only one-sixth part of the air in a division, you have only one-sixth part of the workings to ventilate with that air, and the gas discharged in the return air passages as before stated, is conducted away from, and not into the workings.

Son: Is this mode not adopted because the distance is not the same for air to travel as in the other?—*Father:* No, that cannot be the cause, as air will travel a short distance much better than a long one. To split the air into parts and ventilate each working part separately, one division of air will only have to travel around one part, and not around six; and air will travel around one much better than around six, as a person will travel one mile with a load much better than six.

Son: Is it not adopted because there is not the same work for the furnace to produce ventilation by it as by the other?—*Father:* I cannot see that the work of the furnace will be any inducement for not adopting the mode, but a very strong one why it should be adopted; because if air only travels around one part instead of six, and also one division of air occupies the same space in the air-passage as six would, the friction of that air will be very much diminished; and if the friction is much diminished, the furnace will produce for the workings a larger quantity of air, because the quantity of air produced by a furnace is always in proportion to the friction required to be overcome by it. Diminish the friction, and the furnace will produce a larger quantity of air in proportion.

Son: Is this mode not adopted because falls of the roof may affect the air-passage, and not so by the other mode?—*Father:* There is more danger of falls affecting the air-passages by ventilating many workings with one large current through one air-passage, than by ventilating each separately, because, if there is

I wish to know, if in those mines under your charge, you have always adopted the mode of separate distinct currents of air, that is, changed from the old to the new mode of ventilation ?—*Father:* I have had charge of several mines in Yorkshire and Lancashire, and in those mines which gave off much explosive gas, I always changed from the old mode to that of separate distinct currents, and by so doing prevented, I believe, much loss of life and property.

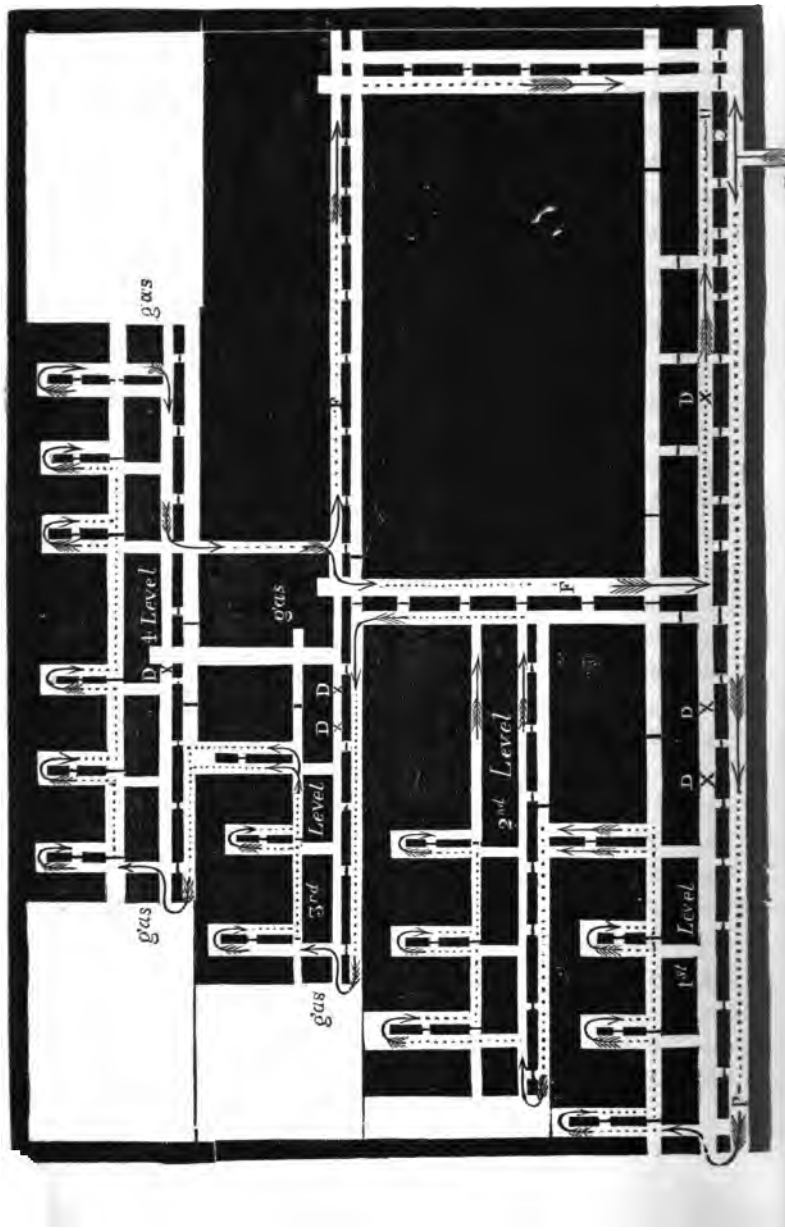
Son: You have had no great loss of life by explosions, you say, in mines under your charge; but you may have had little or no explosive gas in such mines, and that may be the reason you have had little loss of life.—*Father:* Like others, I have had mines varying in the quantity and quality of the gases discharged, yet few have had, I think, more explosive gas to contend with. I have seen men affected and struck down by it in a moment's time, and have seen it ignite and explode in the safety-lamp. But my method of ventilation to prevent loss of life and property has always been—1. To obtain all the air possible for the workings.—2. Not to have more works to ventilate than pure air can reach.—3. To ventilate those workings which discharge much explosive gas separately.—4. To conduct explosive gas away from the miner, and not to him, for there is a right and a wrong way of conducting air and gases from the workings of a mine. To illustrate my meaning, suppose a number of chemical works are near a large population, who are affected by breathing impure air when the wind blows from the works towards them. But in case a change in the wind takes place, by which the noxious gases are blown in an opposite direction; they would breathe a purer atmosphere even if the force of the wind be not one-twelfth of that which blew the gases to them, as no gas can come

against the wind, be its velocity ever so small. And so in like manner is the ventilating of mines, if air be properly conducted around them. Miners' lives are often jeopardised by managers conducting the whole of the gases into and upon the tram-roads and waggoners.

Son: When you were first engaged at a colliery in St. Helens, you adopted, did you not, separate distinct currents of air.—*Father:* Yes, I did; because I found in one mine much explosive gas discharged. The men had to work with red-hot safety-lamps. The discharge of gas was so great that coals were lost, as a safety-lamp could not burn, nor the place be approached with one; and in the waggon roads, gas often ignited in the safety-lamps hundreds of yards from the working faces. As this state of things was so bad, I drew a plan to show my employer it was possible to make a change in the mode of ventilation, and adopt separate distinct currents of air for the workings, and he having a good knowledge of mines and mining, was at once convinced it would be much better for the safety of the men. He ordered its adoption, fearless of expense, but I assured him it would not cost £3.

Son: I shall be glad, father, to see the way by which coal was worked out, and how the mine was ventilated, and also the improved mode you adopted.—*Father:* If you change the mode of ventilation, it will not do at all times to change the mode of working out coal, because another mode of working may not answer well for the seam of coal; therefore, in making a change in ventilation, you have often to contend with difficulties, because you cannot make air-gates in places you wish. I may also add, if a person has not got the ability to make a change in the mode of ventilation, without changing the mode of working

PLAN No. 5.

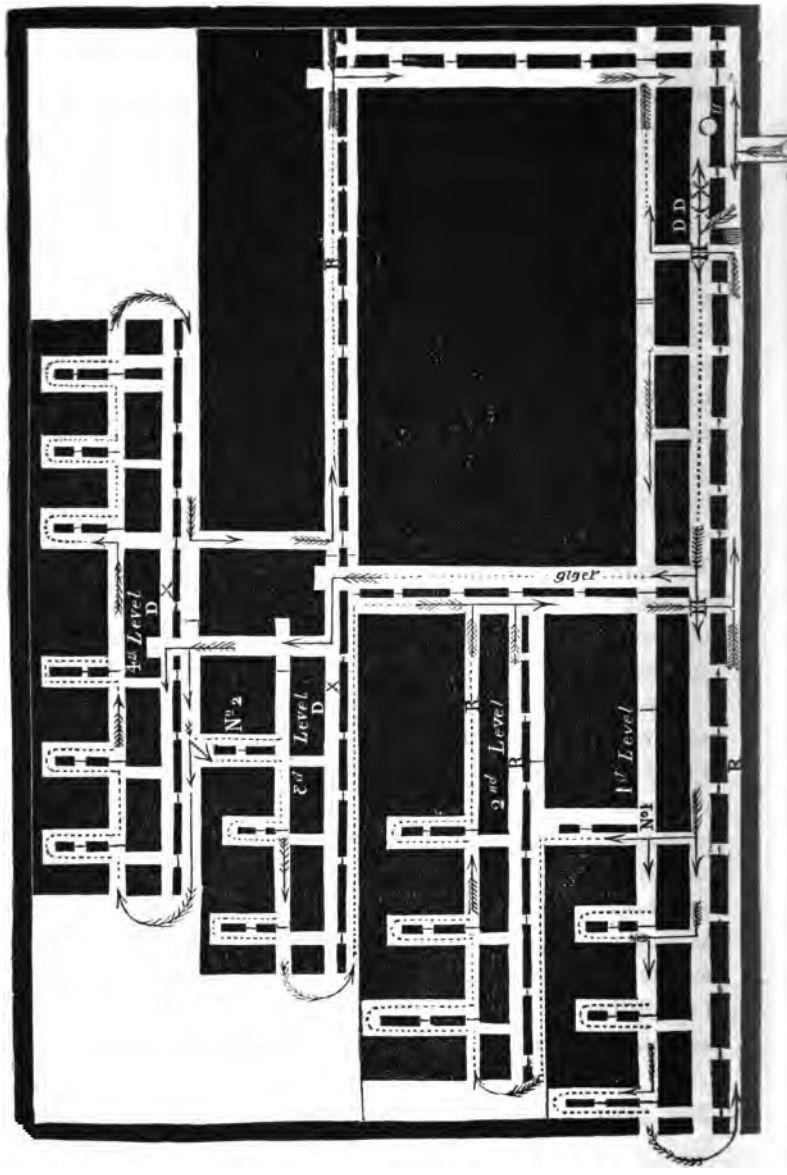


out coal, he is not a proper person to take charge of the underground workings of a mine. In the mine in question I had to make a change in the mode of ventilation, and not in the way of working out the coal, which may be seen in the two plans, Nos. 5 and 6, before you. Plan No. 5 is a representation of how the mine was worked and ventilated when I first took charge. Plan No. 6 shows the same mode of working the coal, and the change I adopted in the mode of ventilation. You will see in plan No. 5 that the air enters the down-cast, and passes on in the lower level to the letter P, a distance of nearly 800 yards, after which the air passes forward through and around all the workings in one continued route, in one current.

Son: Very good. But what am I to understand, father, by the other letters on the plan?—*Father:* The letters D D are for doors. F F show where gas often exploded in the safety-lamp. You see the third and fourth levels. Well, in those levels the discharge of gas was so great that safety-lamps could not burn, and the coal had to be left until the change in the mode of ventilation was adopted.

Son: In looking over plan No. 6, I see that the pure air passes out of the lower level into the waggon road, and onward to the jig brow, where the air divides itself to pass to the third and fourth levels. One division takes place at No. 1, and at No. 2 another division of the air takes place, so that each level, I see; is ventilated separately, as fresh air enters from the down-cast for each level. Therefore, each level will only have its own gas, and not gas conducted from the first, second, and third levels to the fourth.—*Father:* Such is the case. By this mode of ventilation the gases discharged in one working place do not pass into the workings of another level, you send pure air into

PLAN No. 6.



the workings on the waggon roads, and not as before, impure air; the impure air is conducted from the workings on roads not in use for waggoners.

Son: I presume, father, an air-crossing is fixed at the letter H, and also a regulator at the letter R, and doors at the letters D D?—*Father:* You are right, my lad, such is the case. I only show these plans to give you a knowledge of the two ways of ventilation, and also which is the best. By one way coal was left, but not so by the other.

Son: Did you clear the gases away, after your plan was adopted?—*Father:* Yes; the men were able to work with naked lights after, in nearly all the places; and we also got out the coal, which had been left where a lamp could not burn, or be got near to, before the change.

Son: No doubt the men would be very glad when the change took place.—*Father:* It may be well to relate what took place at the time. You know that miners have a notion that employers seldom change their managers for the better. I was one of those who they thought made things no better; so when the change took place, up came the men out of the pit, and stated to the master that fire (explosive gas) was in their places. The fireman being there at the time, and hearing what they had got to say, and having himself just come up out of the pit from the workings, he said to one—"Well, Jack, what's thou come up for?" Jack: "I reckon we've come up for fire." Fireman: "Is there any fire in thy place?" Jack: "No, but there is in others, I suppose." So he (the fireman) said to another: "Well, Bill, what's thou come up for?" Bill: "I have come up for fire, like others." Fireman: "Is there any fire in thy place?" Bill: "No; there is no fire in

my place, but there is in others, I suppose." So the fireman questioned Ned, Tom, Bob, Sam, and Charley, all in a similar manner, and each was able to work in his own place with safety, but had come up because "others could not work for fire."

Son: Did you say anything to them, father, all the time?—*Father:* I allowed them to say all they had to say, as I knew that the truth will always make its way. Their object having been seen by the master, and by every person there, I said, "You know, men, before the change took place, you had to work with red-hot safety lamps, and some of you had to give up working coal in your places, because the discharge of gas was so great that a safety-lamp could not burn, and coal was lost in consequence, and gas often exploded in the safety-lamps hundreds of yards from the working places along the waggon roads. Therefore, I wish to prevent loss of life, because I also may be lost, if you are." If an explosion had taken place, a great number would have been lost.

Son: Did you say anything more?—*Father:* The master said many heads had many minds; therefore, it would be well for them to find a better mode of ventilation, and, he said, no doubt I shall be glad to adopt it. I assured them I would adopt it with great pleasure.

Son: Did they find, then, a better mode of ventilation?—*Father:* No. I offered to give two pounds to them or any person who would draw me a plan of ventilation as good for their safety as mine; but home they went, and I cannot say whether or not a fight took place on the road, as one said, "I should not have come up had it not been for thee;" and another, "I should have been working had it not been for thee;" "I

had no cause to come up," said another; so they charged each other for not being at work.

Son: Did they try to show any more faults in your mode of ventilation?—*Father:* Yes; they said I had caused the roof to fall in the tram-roads by changing the mode, and the waggoners said I had made the roads too cold, and they would be "starven" (starved.)

Son: How was it, father, that they would be "starven," as they called it?—*Father:* Because before the change they had to work in warm, impure air, but afterwards in cold, pure air. Yet those miners were good workmen. They were under my charge a long time, and, I believe, sorry afterwards for the opposition they had given, as they knew it was much better for their safety. Many left when the pit was finished, and engaged at a new colliery in the neighbourhood, where much explosive gas was discharged, and as they had seen the great change for the better in the mode of ventilation I adopted, I was requested by them to engage with their new master, because they had great fears of an explosion, which they said would cause great loss of life if it took place, but would be prevented by adopting the improved mode of separate distinct currents of air.

Son: You did not engage, did you, with their master?—*Father:* No. I had a note from him, with a request to see him, and he assured me if I wanted a situation he would engage me; but as I had one, and had no wish to change, and as my employer was in the same mind, I remained where I was for six years longer; I afterwards engaged at the said new colliery.

Son: Then you did engage after a few years?—*Father:* Yes.

Son: Was the colliery extensive, and one that discharged much explosive gas?—*Father*: You may judge how great was

the quantity of gas discharged, when I inform you of the extent of the workings; also there is a letter which appeared in the *Mining Journal*, April 15th, 1870. Here it is:—

AN IMPROVEMENT IN COLLIERY VENTILATION.

GIVE HONOUR WHERE HONOUR IS DUE.

Sir,—As the subject of colliery ventilation is one of vast importance, the management of our mines ought to be in the hands of sober, careful, and intelligent men. It is some time since the inspector of this district found it necessary to stop one part of a large mine, on account of it giving off a large quantity of explosive gas, and the workmen's lamps were, therefore, unsafe to work with. The ventilation was miserable in the extreme, as it was conducted on a wrong principle—throwing the body of gas on to the men instead of taking it from them. This, then, was the real danger. Some few months ago, Mr. W. Hopton, who wrote the "Conversation on Mines between Father and Son," was engaged to conduct the underground workings. Mr. Hopton very soon gave instructions for some alteration in the ventilation. Having improved the main return air-way, he next proceeded to divide the current into so many separate divisions, thus giving each level or brow a current of pure air to itself, which had the natural effect of clearing the places of gas and keeping it from the men; and instead of the lamps being in danger, the men can now with perfect safety work with naked lights.*

Mr. Hopton, after years of anxious exertion, has won for himself in this district a name of honour, trust, and deep respect from all classes of society, by making the mines safe where our miners have to earn their bread. Now, sir, if the Government should call for Inspectors, I think Mr. William Hopton ought to be nominated for this district, believing in such a position he would not fail to take his place among the intelligent and honourable practical mining engineers of this country. His manly and careful exertions in making peace and creating good feeling between masters and men, also gives him a place among the nobles of our land; and the wonderful change for the better he has made will, perhaps, save thousands of pounds and many a poor miner's life.

EDWARD A. RYMER,
St. Helens, Lancashire, April 15th. Miners' Agent.

* In a mine so extensive and discharging such large quantities of gas, Mr. Hopton would not allow naked lights to be used, for miners often run with lights where they should not.

Son: According to this a large quantity of gas was discharged; but how extensive was the colliery?—*Father:* Well, the length of levels direct from the pit shafts was 2,700 yards; and in breadth there were 11 levels 60 yards apart. Depth of shafts, 440 yards. The winding engine was 300-horse power, and it wound up six large boxes at once, which, with the cage, make a weight of six tons, and 20 persons were wound up and let down by the engine at once.

Son: You must have had a large quantity of gas in a mine so extensive.—*Father:* Yes, we had.

Son: I am very glad, father, you had no loss of life there, and that the men at the old colliery knew that your mode was the best for the preservation of their lives.

PRESENTATION TO MR. HOPTON.

On Saturday, October 29th, 1870, a lecture was given in the Town Hall, St. Helens, by Mr. William Hopton, colliery manager, author of the "Conversation on Mines between a Father and Son." Edward Johnson, Esq., colliery proprietor, presided.

The lecturer spoke on the useful properties of the atmospheric air, its composition, and how mines are affected by its variations in weight; the composition of explosive gas and after-damp, and when mines are in the greatest danger, &c. The lecturer showed gas in the safety-lamp as seen in a mine when it explodes, and also exploded a miniature mine. He gave experiments on oxygen, hydrogen, nitrogen, and carbonic acid gases. He remarked that there always had been, and he feared always would be, explosions under the best managers; yet he believed that if a proper system of ventilation were adopted, and firemen and deputies understood better the laws of nature, the loss of life would not be so often, nor so great when they did take place. Many lives had been lost, he believed, and men often worked in jeopardy in explosive gas, when the danger might at once be removed if they only knew nature's laws better. The lecturer was well received, and the chairman, in his closing remarks, said that all must have been highly gratified. He believed such persons as Mr. Hopton were much needed, and hoped it would not

be the last lecture he would give them. At the close of the lecture, Mr. Hopton was presented with a gold watch, albert chain, and pocket compass, and on the watch was engraved the following inscription :—

"*Presented by the miners of the St. Helens Colliery to Mr. Hopton, manager, as a mark of their esteem and appreciation of his services.*" *October 29th, 1870.*

The watch was a gold centre seconds lever, by Mr. James F. Hilton, St. Helens, jewelled in ten holes, with compensating balance.

Mr. Leivesley, a fireman at the firm, and one on the committee of seventeen persons chosen by the members of the St. Helens Collieries, numbering over five hundred hands, and in the employ of Pilkington Brothers, in presenting the testimonial said :—"I rise with feelings of pleasure to present this gold watch and albert, willingly subscribed by them as a mark of respect and the high esteem you are held in by them for the valuable services executed by you for their safety. Wishing prosperity may always attend and crown your labours in the management of other collieries, as it has in that of the St. Helens collieries, the men believe that honour ought to be given where honour is due. They remember the great danger they had in working very much in explosive gas when first you took charge, and the great change for the better effected by your arduous study and labour for the safety of life and property, and for which this gold watch is presented as a mark of the high esteem and approval of your services."

Mr. Hopton said—"Mr. Chairman and friends—This useful and splendid gift is an honour I never expected—the gratitude for which is too great for my tongue to express the emotions of my heart. This splendid gift will be valued by me as long as memory holds its seat, and by my children's children when my bones are mouldering in the grave. I have not done more than my duty, and what every person should in similar situations—endeavour always to protect life and property. I have now left the collieries, having given a proper written notice to William Pilkington, Esq., who engaged me, for reasons best known to myself. I have left on friendly terms, as you may tell, having continued on their account, one fortnight after the expiration of my notice. The St. Helens collieries are very extensive, discharging much explosive gas, the workings of which were not, you know, very healthy when I came to them; but in June, 1869, a great change in the ventilation of the mine took place. Twenty-two persons it required separated in the workings one-and-a-half miles from each other—every one having his duty to do in the same second of time; and, after timing all the watches,

I said, 'Go, men, to your stations; keep awake; let each one do his duty, not before or after, but at the same second of time; and, if so, be assured success will crown our labours.' I know many prophesied that in its accomplishment we should all be blown to pieces; but having studied well my plans, I knew that success depended only on every person doing his duty at the proper moment, and when it arrived no tongue can express the anguish of my heart, when opening a door, with my watch in hand, I exclaimed to myself, 'Are all at their posts doing their duty?' And when only half opened I felt the reversion of the current, and with that reversion a tremendous wind which blew my light out and the cap off my head, and I again shouted at the top of my voice, and my heart went also with it, 'Yes, yes, everyone has been in his place and doing his duty.' Yet, I must tell you the dangers are not all past; now and again sudden outlets of gas take place which will require great caution and care; but be assured nothing on the part of the employers will be wanting that they can do, if they know, for your safety. I advise you to work honestly; do labour equivalent for your wages; for the success of your employers is closely connected with your prosperity. I thank you again and again for this splendid gift."

A vote of thanks was passed to the chairman and lecturer, when the meeting terminated.

Mr. Hopton was four years at the St. Helens collieries; after which he "re-engaged" as manager at the Sutton Heath collieries, for James Radley, Esq., with whom he had served nine years previously, and is yet with him in 1883.

Son: Have you any more plans on ventilation?—*Father:* Yes. I will show you another, and then I have done. It is one on separate currents of air for the workings. See plan No. 6. This plan is very good. The up-cast, No. 2, is much larger than No. 1, the down-cast.

Son: Is the shaft larger because the air expands when made hot, and by the up-cast being much larger there is room for the expansion of the hot air?—*Father:* Yes. There are also four separate divisions of air direct from the down-cast shaft. Those four divisions all come into the up-cast by four separate ways.

Son: By what you have said you strongly recommend that

mode of ventilation, and the up-cast being larger than the down-cast. But what am I to understand, father, by the letters H, X, and R, on plan?—*Father:* The letter H shows where the impure air from the workings crosses the pure air. The letter R shows where the air should be regulating. The letter X shows where doors are fixed to allow the tramboy to pass in and return from the workings.

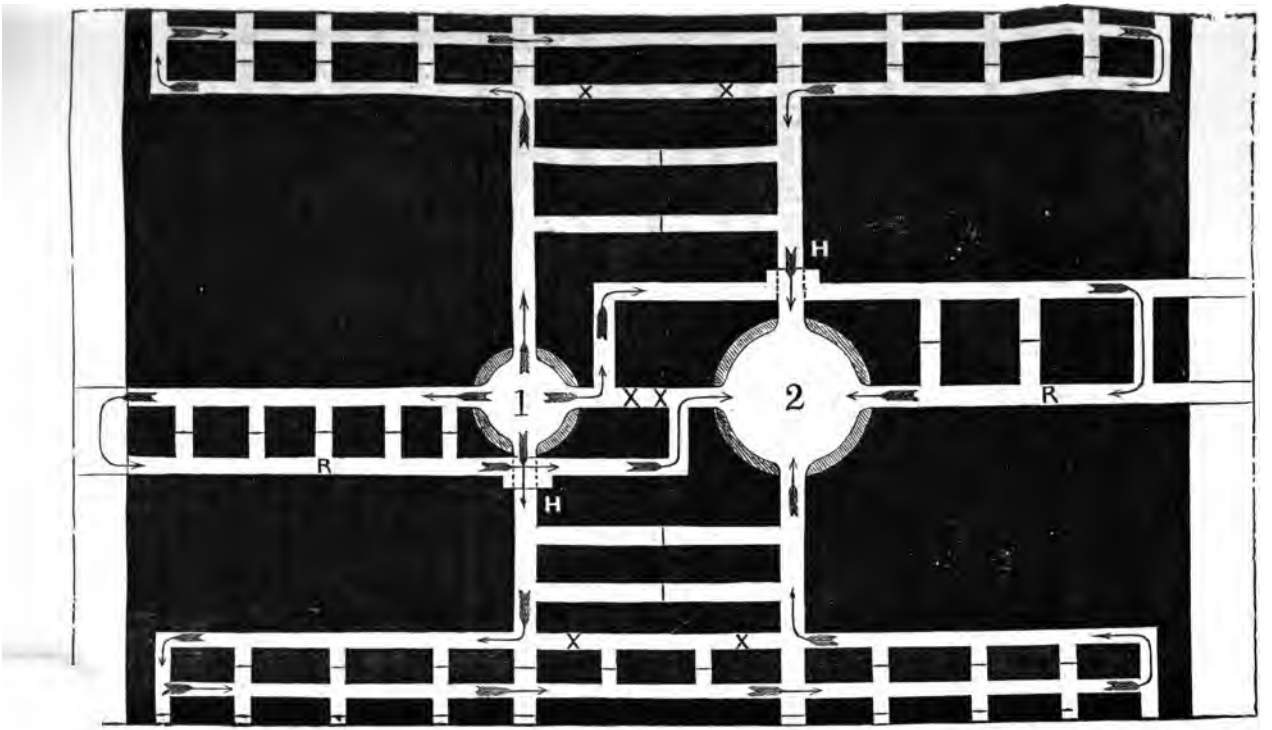
Son: Very well. I am glad for your explanation how mines are ventilated.

Friction of Air in Mines.

Son: I wish to have a little conversation now in reference to the friction of air in mines.—*Father:* I shall be glad to give you all the information possible in reference to the "friction" of the air, as it is a very important subject.

Son: Friction is caused, I understand, by rubbing or dragging one body against another?—*Father:* Anything dragged along or rubbed against another substance produces friction. To illustrate this more clearly, I will show you that friction may be produced in several ways. Firstly, a ball will not roll the same distance on gravel as on ice, because on the ice there are fewer obstacles then on the gravel; and the rubbing or friction of the ball against the gravel retards its progress. Secondly, a break pressed against a fly-wheel when in motion produces friction; and more pressure added to the break will increase the friction until the flywheel comes to a standstill. Thirdly, in proportion to the area of the surface rubbed, so is friction produced—that is, if only one square yard of surface is rubbed, the friction will be only one-fourth of that caused by rubbing four square yards of surface. Fourthly, friction is diminished or increased accord-

PLAN No. 6.



ing to the velocity the air travels at; by doubling the velocity you increase the friction four-fold; that is to say, if a vessel at sea can only be propelled 20 miles in a certain space of time by an engine of 100-horse power, it will require an engine of 400 horse-power to propel it the same distance in half the time, because friction increases as the square of the velocity.

Son: What do you wish me to understand, father, by the rolling of the ball on the rough gravel, the pressure of the break on the fly-wheel, the friction produced by the large and less area of surface rubbed, and the increased power required to propel a vessel to travel at a double velocity? That is, am I to understand that friction of the air in mines is caused by the same?—*Father:* By the above, I hope to show that friction of the air in mines is produced in four different ways. In passing air through and around the workings of a mine, it presses against the roof, floor, and sides, and, by such pressing friction is produced; and it is so great in some air-gates that the air may be heard to make a noise or sound as it rushes through them. Therefore, if air-gates be not smooth, even, level, and free from obstructions, but are rough, rugged, unequal, and not regular, they will produce more friction than if smooth.

Son: I see now that if an air-passage be smooth, the air will rush through it with less friction than if rough, just as a ball will roll better on the ice and with less friction than on gravel.—*Father:* Yes, and the longer the air passages the more is the friction produced; and, if air is propelled around six groups of miners, the friction, drag, or the rubbing of that air against the roof, floor, and sides, will be much greater than that produced by conducting the said air around one division of miners; and, as the flywheel comes to a standstill by the great friction or

pressure upon the break, so also will air come to a standstill, from being compelled to drag, or rub through a large space of surface,

Son: I also see, father, that as there is more friction produced in rubbing four square yards of surface than one, so is there more friction produced by conducting air around six divisions of miners than one; and, as you say, the flywheel comes to a stand by the great friction of the break, so will air also in mines come to a stand, if the distance be too great for it to travel. But, father, you say there is another way by which friction of the air is produced in mines—that is, by its velocity?

Father: If you cause air to travel at a great velocity, you increase the friction very much. You have seen ships at sea or vessels in a canal propelled by the force or power of the wind, at a great speed, because the force of the wind against the sails of the vessels was very great. Now to propel a vessel forward at the same velocity, if there was no wind, would require an engine of great power. Well, if the force of the wind which propelled the vessels forward at such velocity were increased four-fold, the vessels would only travel at double the velocity. So, in like manner, is ventilation in mines. If 20,000 feet of air can be produced for the workings of a mine per minute, by the power of a furnace, it will require the furnace to be increased in power four-fold, to produce double the quantity of air, because, as before stated, the friction of the air increases in the same ratio as the force, and the force increases as the square of the velocity. As that is the case, it requires four times the power to produce double the quantity of air, and sixteen times the power to produce four times the quantity of air, because the rubbing of the air against the roof, floor, and sides,

which produces the friction, is very much increased by the velocity.

Son: Suppose, father, two divisions to be of unequal lengths, one 800 yards from the down-cast to the up-cast, the other only 400 yards, and the area of the air passages each to be nine feet. I wish to know why air rushes with greater velocity along the shorter route than on the longer one?—*Father:* Because the area of surface rubbed in the shorter one is only one half of that in the longer one, and therefore, there is less friction in one than in the other; or, in other words, the balance of friction in the two is not equal; an increased velocity produces friction, and as there is less friction in the shorter route, the air rushes in at a greater velocity to equal the balance of friction between the longer and shorter route.

Son: Will you explain to me the method you use to find the quantity of air each takes?

Father: In order to do this, I will ask you a question or two on what I have told you with regard to the laws which relate to friction. If the length of an air-way is increased to four times what it was originally, what is the effect on the friction of the air current?—*Son:* The friction is also four times as great as before.

Father: But if the velocity of the air current be increased to four times its ordinary velocity, the air-way not being altered, what is then the effect on the friction?—*Son:* It is sixteen times as great, because the friction varies as the square of the velocity.

Father: Very well; but suppose the air-way to be reduced to one quarter its length, what will be the friction?—*Son:* It will be reduced to one quarter also.

Father: Now, I will ask you a more difficult question, but I have no doubt of your being able to answer it provided you have thought well over what I have told you.—*Son:* I will do my best to answer it to your satisfaction.

Father: If the velocity of the air current be reduced to one quarter its previous rate, how will the friction be affected?—*Son:* It will be reduced to one-sixteenth.

Father: Why so?—*Son:* Because as the friction varies as the square of the velocity, it follows that the velocity being one quarter, the friction will be $\frac{1}{4} \times \frac{1}{4} = \frac{1}{16}$, or $\frac{1}{4}$ squared.

Father: If the friction varies as the square of the velocity, does it not follow that the velocity varies as the square root of the friction (that is, the friction due to the velocity)?—*Son:* Yes, of course; for if we represent the velocity by 2, the friction will be represented by 4, and the square root of 4 (that is the friction) is 2; again if the friction due to the velocity be reduced to 1, the velocity will be reduced to 1 also, because the square root of 1 is 1.

Father: Now, if one air-way be four times as long as another, the friction due to the area of rubbing surface will be four times as great in the longer one as in the shorter one, and therefore a current of air would travel faster through the shorter one than the longer one. Can you tell me how much faster?—*Son*: It will travel twice as fast, because it causes as much friction in each foot of the shorter one *by travelling at twice the velocity* as it does in four feet of the longer one.

Father: But suppose that both air-ways are being supplied from one large current, will the shorter one take twice as much air as the longer one?—*Son:* Yes; because until the velocity in the shorter one is twice as great as in the longer one, the

friction in it will be less, and it will therefore offer less resistance to the air, and consequently the air rushes that way in preference, but as the velocity increases the friction so rapidly, it soon brings it up to what it is in the longer one.

Father: If two air-ways of the same area be 200 and 800 yards long respectively, and they are supplied with 12,000 feet of air per minute, what quantity would pass through each?—*Son*:—The long one is four times as long as the short one, therefore, air travelling along it at a certain velocity, which we call 1, has four times as much friction to overcome as if it travelled by the shorter one at the same velocity; and as I said before, the friction in the shorter one will be made equal to that in the longer one, by the increased velocity; therefore, it follows that if we represent the friction in the longer one by 4, the friction in the shorter one is brought up to 4, by the increased velocity. But the velocity varies as the square root of the friction, and as the friction is 4, therefore the square root of 4, *that is 2*, is the velocity at which it would pass. Thus the velocity in the shorter one is twice that in the longer one, and the quantity passing is consequently 8,000 feet per minute in the short one and 4,000 in the long one.

Father: As you seem now to understand the reason that it differs, I will give you a method of arriving at your result, which may be applied to any number of splits. Rule:—(*a*) Assume the friction due to length in the shortest air-way to be 1; find the lengths of the others according to this standard; *thus* $1\frac{1}{2}$ *times the length would be* $1\frac{1}{2}$ *twice the length* 2, *and so on.* (*b*) Now make the units of length in the longest, the standard of friction to which you assume all the others will be made equal by increased velocity. (*c*) Divide this by the figure which represents

each air-way; and (*d*) find the square root of the result. This gives the relative velocity at which the air travels in each air-way. We will now take an example: Suppose you had five divisions—the air to travel in the first division 200 yards; in the second, 400 yards; in the third, 600 yards; in the fourth, 800 yards; and in the fifth, 1,000 yards; the sectional area of each air-way being alike, and the total quantity of air to pass 72,260 feet per minute. What quantity would pass along each air-way if there were no regulators fixed in any of them? Referring to the rule, by (*a*), we make the friction in the first (the shortest) 1, the second 2, the third 3, the fourth 4, and the fifth 5; then by (*b*) we have 5 for the standard of friction, to which all five will be made equal; then by (*c*) we have:

First	$= \frac{5}{1} = 5$;	$\surd 5$	$= 2{\cdot}236$
Second	$= \frac{5}{2} = 2{\cdot}5$;	$\surd 2{\cdot}5$	$= 1{\cdot}581$
Third	$= \frac{5}{3} = 1{\cdot}\dot{6}$;	$\surd 1{\cdot}\dot{6}$	$= 1{\cdot}291$
Fourth	$= \frac{5}{4} = 1{\cdot}25$;	$\surd 1{\cdot}25$	$= 1{\cdot}118$
Fifth	$= \frac{5}{5} = 1{\cdot}$;	$\surd 1$	$= 1{\cdot}$
			$7{\cdot}226$

We now have the relative velocities at which the air will travel in each air-way, and in order to find the quantity which will pass in each we must divide the total quantity of air per minute, that is 72,260, by the sum of the relative velocities, namely, 7·226 we find this to give us 10,000, and it is evident that by multiplying each of the air-ways by 10,000, we shall have the quantity of air passing in each per minute, thus:

First	$= 2{\cdot}236 \times$	10,000	$= 22{,}360$
Second	$= 1{\cdot}581 \times$	10,000	$= 15{,}810$
Third	$= 1{\cdot}291 \times$	10,000	$= 12{,}910$

Fourth	= 1·118	× 10,000	= 11,180
Fifth	= 1	× 10,000	= 10,000
			72,260

I will now give you one or two easy examples, which you can work out for yourself, as I have merely put the answers to them without showing the working:—I wish to make two divisions of an air current of 24,142 feet per minute, but find that I cannot divide the length of the air passage equally, one being twice as long as the other; what quantity per minute will pass along the shortest route if there is not a regulator fixed in it? Answer: 14,142 feet. If an air current of 27,320 feet per minute is divided into two parts, so that one has to travel three times as far as the other, how much will the short one take more than the long one in half an hour? Answer: 219,600.

Son: Will not the total quantity passing be increased by dividing the air in these cases?—*Father:* Certainly, if the power which caused a current of 27,320 feet per minute in the last example was not decreased, it would produce a much greater quantity after the division; but I have assumed the quantity given to be as much as we require, and that the power would be reduced so as to produce the same quantity, but at a less expenditure.

The great friction of the Air by one mode of Ventilation, and how it may be reduced by another.

Son: I see, father, by conducting air around a long route of working places, such workings will lose much air; also, to make one large current of air from many divisions, and propel the

whole quantity through one air-gate of the same area as one of the divisions, the friction of that air must be very great?—*Father:* To show the increased friction by ventilating a great number of works with a large current of air, I will suppose 38,016 cubic feet of air to ventilate the workings of a mine, in which there are say six separate groups of miners, and the area of each gateway is nine feet. To split the whole wind into parts, and ventilate each group of miners separately, each would have, per minute, 6,336 cubic feet of air. This being the case, the air would rush into each gateway, and through the workings, at the rate of eight miles per hour, and its force on one square foot would be a little more than five ounces. Well, but if all the six divisions formed one large wind of 38,016 cubic feet, and the whole quantity had to pass, per minute, through the nine feet area around all the six divisions, it would have to travel at a velocity of 48 miles per hour, and the force of the current on one square foot would be 11½lbs., because the force is increased as the square of the velocity.

Son: There is a great difference, father, between the one and the other, the propelling force of separate currents is only 5oz., and in the other case 11½lbs. Yet the quantity of air produced is the same. The air rushes with a force 36 times as great as if each part be ventilated separately; therefore, what difference is there, father, between the friction of one and that of the other?—*Father*: Well, by one mode, you see, the air travels around six parts, but by the other only around one, consequently, as one large current will have six times the velocity as six separate divisions, the friction will be $6^2 = 36$ times as much; but this is not all: the distance that it has to travel is six times as great, therefore we have six times as much friction caused by the-

distance in the long one as in the short one, which makes the total amount of friction $36 \times 6 = 216$ times as great by one large current as by six separate divisions. Because the friction in this case is of two kinds—one is in proportion to its force or velocity, the other in proportion to the distance it travels.

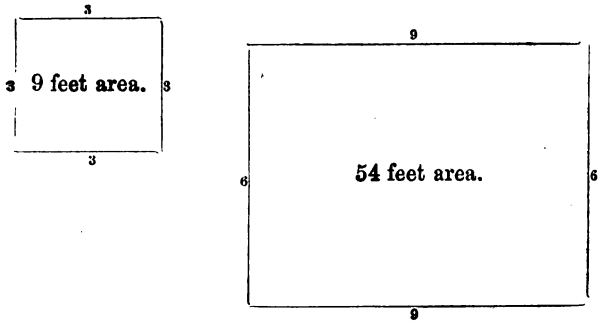
Son: To enlarge the air-gates would prevent this great friction of the air.—*Father:* Yes, but look at the expenditure; the air-gates would require enlarging from nine feet to fifty four feet area. This enlarging of air-gates could not be maintained at every colliery.

Son: But it would, as you say, diminish very much the friction by enlarging the air-gates.—*Father*: So it would.

Son: To have all the air passing, as you say, through a nine feet area, the friction would be very great; and to pass the same quantity of air through six air-gates, each of nine feet area, would diminish the friction very much. But, father, would not the friction again be much diminished by enlarging from six air-gates, each nine feet area, to one of 54 feet area?—*Father:* Yes, the rubbing surface would be much less in one 54 feet area, than in six air-ways, each nine feet area; therefore, the friction would be less.

Son: How much would the rubbing surface be less in one of that area than in the others?—*Father:* The rubbing surface of the six small ones would be $12 \times 6 = 72$ feet; in the large one $(9 \times 2) + (6 \times 2) = 30$ feet only. (*See page* 115.)

Son: I see, father, the rubbing surface is diminished by more than one half.—*Father:* So it is; therefore you see, it is well, if possible, to enlarge the air-gates to diminish the friction.



Son: I think the main returns and intakes, father, should be made large.—*Father:* Yes; but air-gates in the interior of the workings cannot always be kept large, as it would be very expensive to do.

Son: The expenditure would thus be very great, and also in furnace power to overcome that amount of friction, because the furnace, in proportion to its power, overcomes a certain amount of friction.—*Father:* Yes. If the friction of the air be very great, the furnace will overcome it, but produce a less quantity of air; but if the friction be not very great—that is, if the air-gates be large enough for the air to travel, the furnace will produce a larger quantity of air for the same amount of friction.

Son: Is not the furnace fixed, father, near to the up-cast shaft, and constructed to hold a large quantity of fire?—*Father:* Yes. But they are not all constructed alike, nor of one size.

Son: If large fires are in mines, will the heat from them ignite the coal, and cause great damage to the underground workings?—*Father:* I have known coal in mines to be ignited by the furnace fire, and the pits to be closed up for months.

Son: Is it possible, father, to construct a furnace by which the coal cannot be ignited?—*Father:* A furnace may be constructed to prevent coal igniting. I have a plan of one so constructed. It was given me by Mr. John Smith, a very intelligent, well-informed person, he was overman for years at several large collieries in the north of England, and is now a certified manager.

Son: I should be glad, father, to see Mr. Smith's construction of the furnace.—*Father:* You may see it with pleasure; this is the ground floor of it. After sufficient space is made in a proper part of the mine near to the up-cast shaft, walls are built, as on the plan. (*See page* 118.)

Son: What are the dimensions?—*Father:* You can make it as large as you think proper. The scale given by Mr. Smith is $\frac{3}{16}$ of an inch to the foot. Mr. Smith gives the plan, but the furnace may vary in size, according to circumstances.

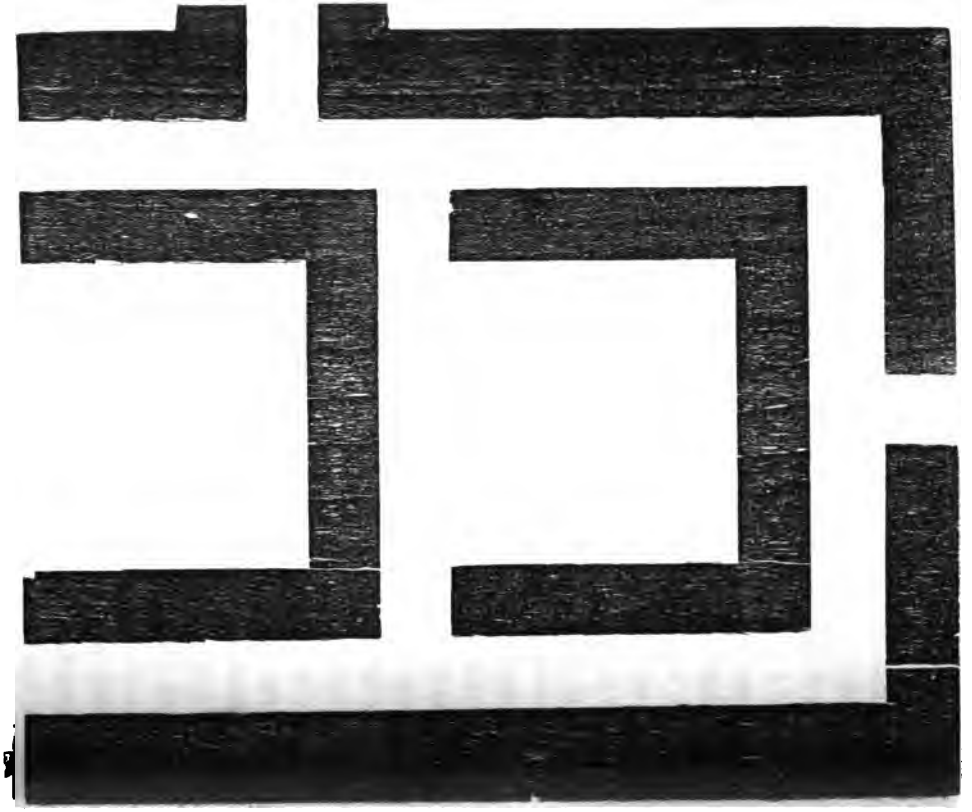
Son: The furnace walls, then, are built sufficently high for the fire-bars?—*Father:* Yes; and from thence upward for the walling of the brick arch, which spans the fire. (*See also the front view on page* 119.)

Son: This is the front view, then, of Mr. Smith's improved ventilating furnace?—*Father:* Yes. You see there are two brick arches over the fire, by which air can pass. Also, two air passages, one on each side of the fire, through which the air cools down the temperature of the fire, between one wall of brick work, and the other next the coal.

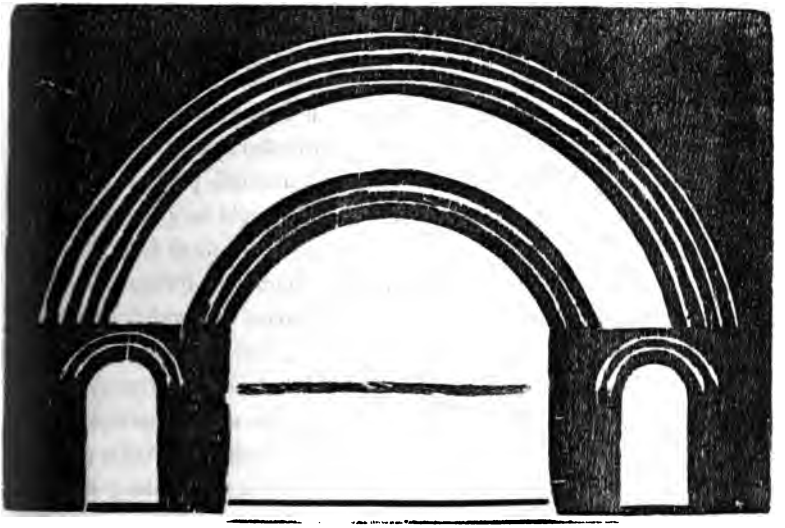
Son: You say this is the front view. Is the back similar to it?—*Father:* Yes, but not exactly so. I will show you the back view; see, here it is. (*See page* 119.)

Son: This is, then, a representation of the back part, the

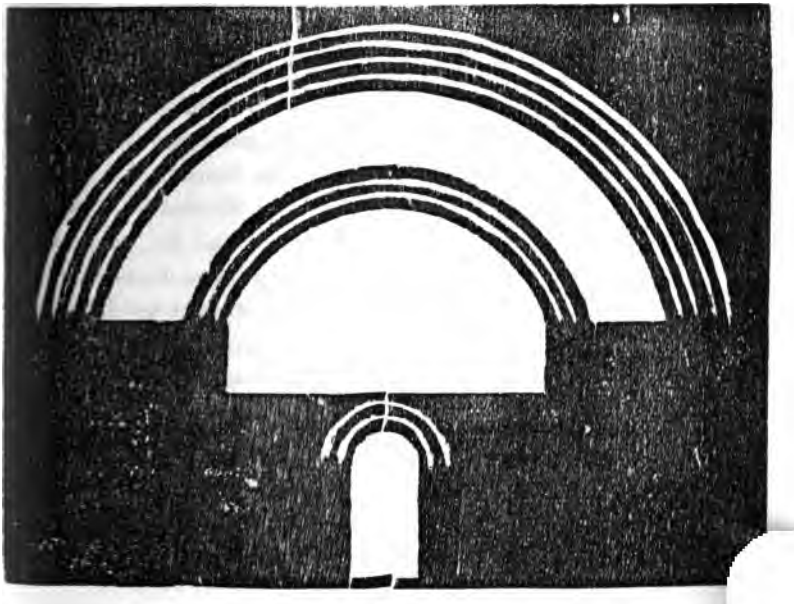
black on the plan being the brick work. The arches, I see, extend across and over the fire, from the front to the back part. I see now, father, how a ventilating furnace is constructed. I think this one is very good, and that it is next to an impossibility for coal to be ignited by the heat from such a furnace.—*Father:* I have shown you the ground plan, the front view, and the back view. I think it may not be out of place to give Mr. Smith's views on furnace ventilation, &c. He says that ventilation is of no recent date; yet man knows nothing, or very little, of ventilation. Coal mining, and its mode of ventilation, was to man unknown, till the effects of impure air were felt, or rather seen, by the candle light, the light being extinguished for the want of pure air, and the approach of carbonic acid gas. Such was the state of things that men were not able to work, as the candle could not burn for the want of pure air, and the approach of carbonic acid gas. Then at this state of things the pit was relieved by hanging a fire-lamp at night in the shaft, to clear the workings of carbonic acid gas by next morning. This continued for some time, but soon failed to produce the desired effect, after which the fire-lamp was fixed at the bottom of the shaft. It answered a little better for a short time; again it was tried with a larger fire or furnace, laid upon flat grates or bars. This answered much better, yet it also had its faults, and I can name several pits burnt by this construction of the furnace. The last improvement is that of making a dumb drift from the furnace to the pit shaft, in the stone roof above the coal, beginning from 50 to 80 yards back from the pit, its rise being, say, from 9 to 12 inches per yard, so that the mouth of the drift will be many fathoms up the shaft. Such dumb drifts were an improvement, but generally they are not attended to, if not



FRONT VIEW.



BACK VIEW.



altogether given up. Therefore, to eradicate the evils which have taken place, I have constructed an improved furnace, and hope others will try to make more improvements.

Son: Did you not show, on the Lund-hill plan, a dumb drift?—*Father:* I did, because I knew it would be an improvement; I was also informed a dumb drift was made at Lund-hill, after the publication of my plan. This improved furnace, says Mr. Smith, will be ventilated with fresh pure air, which I have proved to be a benefit to the furnace, by making it burn and blaze more. Yet, some hold it can make no difference, but they know no better. I ask, can a man, or animal, or fire, do as well with foul air impregnated with impurities, as with pure air? Is it not proved that carbonic acid gas will destroy man, animal, or fire? Therefore it is pure air, mixed with its proper quantity of oxygen, that is required; without it neither man, animal, nor fire can live. Others hold that only a small portion of air can pass over a furnace. This has been the orthodox idea of scientific viewers, who have had little practical experience. But I am able to show, and prove, that almost an unlimited quantity of air has, and can, pass over the furnace. An experiment was tried at North Seaton Colliery, March 19th, 1863, by Mr. G. Scott, viewer, myself as overman, and Mr. Andrew Newton, furnace-man. In opening the separating doors at the furnace, to let in fresh pure air, it was found the air rushed in over the furnace with wonderful rapidity, yet this great gush of air did not diminish, but increase, the air passing around the workings in the interior of the mine. The characteristic of this improved furnace, is a double arch, to allow columns of gas to pass through without coming in contact with the flame of the furnace, which so repeatedly costs both life and property. Flues are provided also to

keep the furnace clean, and prevent it igniting the coal on each side, from which a proper quantity of pure air can be supplied.

Son: I think, father, Mr. Smith's plan of the furnace is very good; I also think with him, that furnaces should be supplied with fresh pure air.—*Father:* I believe many lives have been lost by gas igniting at the furnace; some suppose the explosion at Lund-hill took place at the furnace, and at the time your grandfather was lost, the opinion of many was that the gas ignited at the furnace.

Son: Does not the coal absorb oxygen from the air as it travels along the air-passages?—*Father:* Yes. M. Fabre finds that as coal absorbs rapidly up to one hundred times its own volume of oxygen, the air which the miners have to breathe is deprived of oxygen to a hurtful degree; the atmosphere of a mile is also further vitiated by the gaseous carbon—compounds given off by the slow combustion of the coal. He concludes that a supply of air is more essential than of light, and even the best ventilated mines require better ventilation. This also is in favour of the system of splitting the air, as it has not the same distance to travel, and is therefore not exposed to the same surface of coal.

Several ways by which Coal is worked out in Mines, and why so many methods are adopted.

Son: You have seen and adopted, no doubt, many ways of working out coal since you were first engaged in coal mining?—*Father:* Yes, I have adopted many ways, because I know that the same way of working will not answer with safety and

economy in all mines. One plan of working it out may answer well at one colliery, but not at every one.

Son: Why will not that which answers well at one colliery answer in all mines?—*Father:* Because the nature of the roof, floor, and coal is not alike; neither is the pressure of the roof, nor the discharge of gas in the coal, floor, and roof alike in all.

Son: Do the roof, floor, coal, and pressure, vary much, then, in mines?—*Father:* Yes, at one colliery the floor is soft, but hard at another; in other mines the roof and floor are both soft, in others both hard; the floor lifts in some mines, but in others not so; in some mines coal is hard, but soft in others; the pressure of the roof upon the workings is very great at one colliery, but not so great at another; gas in the coal roof, &c., prevents, at some collieries, tram-gates being cut through the whole coal to the extremity, as there would be no end of the falling in of the roads by cutting them in the whole coal; yet in other mines, if the roads are not so cut, they would fall very much; in some mines the seam of coal is very thick, but in others very thin; also, the seam of coal is flat in some mines, but dips, or rises very much in others; there are many throws, faults, troubles, veins, bad and soft coal in some collieries, but, in others, the coal is all good, and nothing to impede plans in operation. Single tram-gates may be cut through the whole coal at some collieries beyond the current of air, and managers in charge of the same will be able to adopt plans in contemplation, while the discharge of gas in other mines will not allow tram-roads or narrow work to advance two feet beyond the current. The disadvantages in some mines are so numerous that a good profitable way of working out the coal cannot be adopted.

Son: I see now, father, why so many plans are adopted. As you say, one is because the floor is hard, another because it is soft; one is adopted for this thing, and another for that. Therefore I think no person should condemn a plan of working out coal unless he knows well the nature of the roof, floor, and coal, and all the disadvantages connected therewith; as the plan he condemns may be worked with economy and safety where it is adopted, and also may be the best that can be used for that seam of coal.—*Father:* Yet many plans which are not useful, are adopted by managers not having a proper knowledge of the nature of things. Therefore every underlooker or manager of mines should have a good knowledge of the nature of the roof, floor, coal, &c.; and also a good foresight of his contemplated plans. He should have a foresight to see in his mind's eye the plan at work, before he adopts it. If not he cannot see his way clear before him as he should do, but, like a person bewildered in a thick mist, adopts unmatured plans, which will end in injury to the men under him, and loss to his employer. His object should always be to adopt the best plan to suit the seam of coal to be worked out, and not to change because he may see a good plan of working coal drawn well on paper; or may have heard of a good plan adopted at some other colliery.

Son: I presume, father, some mines require much care and attention to produce a good profit for the employers, and ensure safety to the men?—*Father:* Yes; some seams of coal cannot be worked with a good profit if all the plans in use are adopted. So changeable is the roof, &c., in mines, that in some no plan appears to answer well. I have known—and had to manage—mines, where, in one pit, the plan which answers well on the north part, would not answer on the south.

Son: By what you say, I clearly see one colliery would be much better to manage than another. Therefore, no doubt, father, some managers have got a good name for managing, not because their knowledge of mines was superior to others, but because they have a good colliery to manage; while others with a great knowledge of mining, have been discharged and disgraced, because neither they nor any persons were able to make the colliery pay a good profit to their employer. As you have clearly shown the reason why so many ways of working out coal are adopted, I shall be glad to know, father, how or by what ways coal is worked out?—*Father:* One mode is pillar, stoop, or room-working; long wall working another; bank or wide working another; and others work coal out in drifts, yet each and all the ways vary.

Son: What am I to understand, father, by pillar, stoop, or room-working; that is, in what way is coal worked out under those methods?—*Father:* Pillar-working is adopted in several mining districts, but universally in the north of England. To get coal out in pillars, narrow work is cut in the whole coal endways and crossways of the coal, by which square blocks are formed. This mode will find room or places of work for a great number of miners—some in cutting narrow places, others in working out pillars, the pillars always being worked out next to the goaf; that is, one pillar worked out next to the one just finished.

Son: Are the blocks or pillars square, and all of the same size in every mine?—*Father:* No; in some mines they are square, but in others not; neither are all the pillars of one size; they are cut large or small, to suit the seam of coal, roof, or floor where such pillar-working is adopted. If you inspect plan

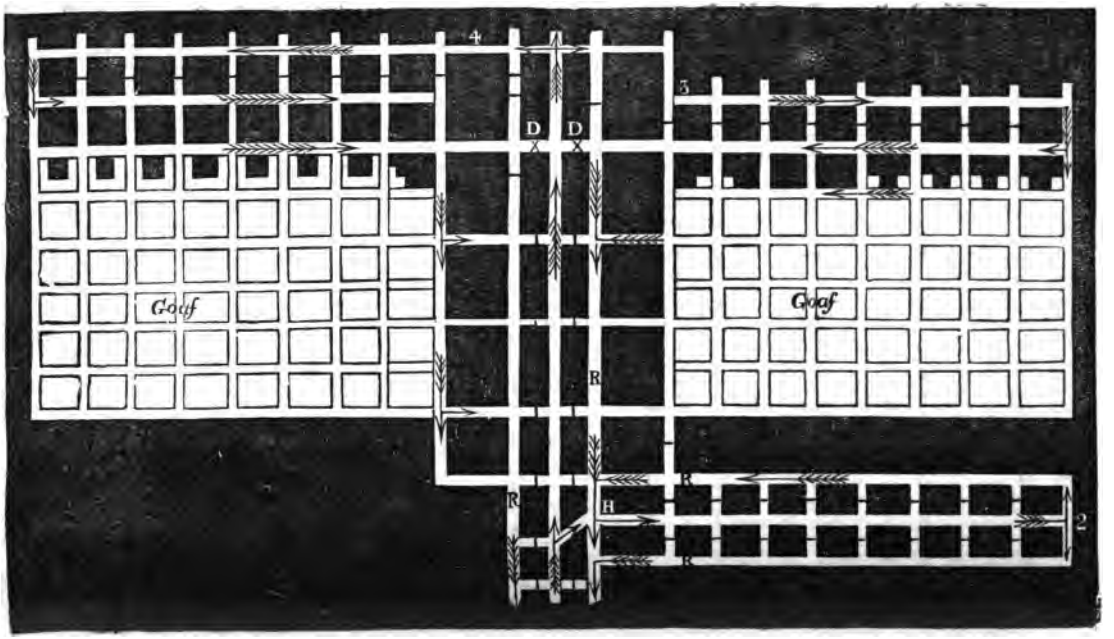
No. 7 (p. 126), and plan No. 8 (p. 78), they will give you a better knowledge how pillar working is carried out.

Son: I see by the plan that narrow places are cut in the whole coal in two directions; this way of working will, I see, make square blocks of coal to be worked out. This, father, is then the plan of coal working universally adopted in the north of England?—*Father:* Yes.

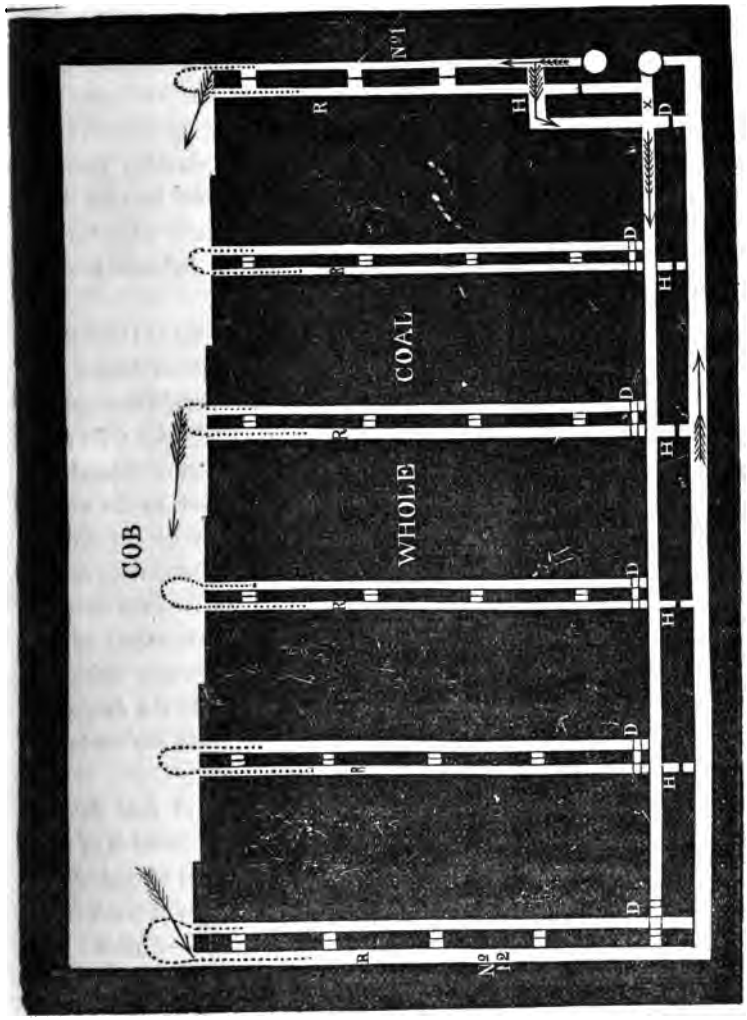
Son: Yet the mode of ventilation on plan 8 is not the same as that shown on this plan?—*Father:* No, this plan shows split winds, and not like plan No. 8, a mixture of winds. If you inspect this plan you will find four divisions for the number of works. See Nos. 2, 3, and 4. The letter H shows the overthrow. The letters R R, regulators, and D D show the position of the doors.

Son: I am glad, father, for the knowledge I have received from you. I think I see, in my "mind's eye," how pillar working is adopted; but how is coal got out by long-wall working?—*Father:* In long-wall there are many ways adopted. One is to work a great number of tram-roads, or narrow places, through the whole coal to the extremity of the block to be worked out; after which, say 100 or 200 yards, or more, is brought back from the extremity, and the goaf left behind. Plan No. 8 is a representation of this mode of working. You see the whole coal, and tram-gates cut through the coal, and also the goaf where coal is got out, left behind. The mode of ventilating the workings is to conduct the air in at No. 1 gateway, from there across the whole breadth of all the working faces to No. 12 gateway, and from there in one current on it goes to the up-cast. As before stated, a large quantity of gases are always collected by this mode. Yet each part may be ventilated

PLAN No. 7.



PLAN No. 8.



separately if overthrows are only fixed at the letters H H, and each separate division of air regulated at the letters R R. In this case all the doors would have to be removed, except the one near the up-cast. Yet this is not the only way adopted for long-wall working, others commence at the beginning to work out a large breadth of working face, say 100 or 200 yards of coal at once, the whole breadth being worked out to the extremity, the tram-roads are made through the goaf, to the working-face, as the face extends into the extremity of the mine.

Son: How, father, are tram-roads cut or made through the old goafs to the working face? Is there not great danger in so working coal out? And, also, are tram-roads made through the goaf, a great distance to the working face?—*Father:* To make tram-roads through the goaf, a stone wall four feet or thereabouts in thickness is built up on each side of the road, as the coal or working face extends forwards. These stone walls prevent the roof falling in, until the pressure brings the roof and floor nearly together, then the floor is either cut up, or the roof cut down in the roads to make them (as the roof and floor meet) of the proper area. When finished, they look like stone drifts or tunnels, and will stand good a long time. As to the danger, it is not so great as in many modes of working; and the roads are cut a great distance through the old goafs.

Son: You say 100 or 200 yards, or more, of coal face is worked out all in one breadth. Can this large breadth of coal be worked out in every mine where the same plan of coal working is adopted—that is, can you see all the men at work from one end of this large working place to the other?—*Father:* No, not in all mines. The breadth of the face of coal worked out is

in proportion to the strength of the roof. If you inspect plan No. 9, it will give you a knowledge of this mode of working. The whole of the coal has to be brought from the face of the workings through the old goaf. The mode of ventilating the workings is to pass the air fresh into every gateway, except at No. 6, at which place the whole of the air meets; after ventilating this place the air goes onward in one current to the up-cast. This mode may be said to be similar to plan No. 2, page 74, by which pure air is mixed with impure air. Yet this mode of ventilation is not good, as the whole of the gases discharged in all the workings are collected at No. 6 working place, so that an explosion there would affect every part of the mine. Therefore, ventilate each pair or tram-gates separately, by passing air fresh up one gateway, and returning it along the other. As to the mode of working out the coal, when the strength of the roof, &c., will not allow the whole breadth to be worked out at once, it is diminished accordingly; that is, two tram-gates work out their own breadth, advancing first into the extremity, other places follow up, one advancing a short space before another, by which the pressure upon the working faces is diminished, as each place takes its own pressure, and does not affect any of the others.

Son: Then I presume, father, when narrow places or tram-roads are cut through the whole coal to its extremity, the entire breadth of the 100 or 200 yards is not brought back all at once? —*Father:* No, not always; it is often worked back in lengths, one before the other, as may be seen from plan No. 8.

Son: I am obliged, father, for your information on long-wall working. I now wish to understand the way in which coal is worked out by *bank* or *wide work?*—*Father:* This method of

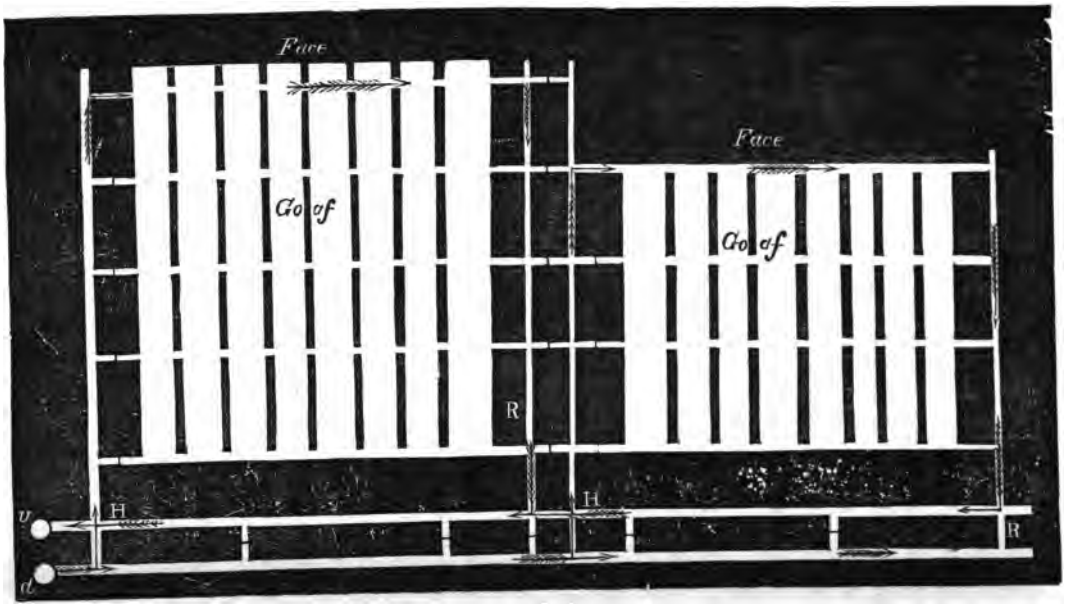
PLAN No. 9.

working is similar to *long wall* or *long work*, excepting that the tram-roads are not made to the working face through the old goaf, but 60 or 100 yards of coal is worked out in one breadth, the tram-roads being cut in the whole coal on each side of the wide breadth of coal worked out.

Son: Is there any pillar of coal left to support the roof where this 60 or 100 yards has been got out?—*Father:* In many the whole is got out; in others ribs of coal, one yard in width, are left at distances of ten yards apart, to support the roof—a hole being made through those ribs or posts of coal through which waggoners pass with coals from the working face, and as the bank face advances, new holes are made through the ribs, by which a new road is made next to the working face. You will have a better knowledge of the mode of working by inspecting plan No. 10, which is a representation of this method. Ribs of coal are left between each working place, and as the face advances, new roads are cut through these ribs across all the working places. This mode of coal getting is also shown in plan No. 4, page 81, the two being similar, except that in one the coal is worked out from the extremity of the block of coal, whilst in the other the working is commenced at the shaft, and continued in the opposite direction. The mode of ventilation on this plan No. 10 is that of separate currents for each bank or working place.

Son: You say, father, to work out coal in *bank* or *wide work*, 60 yards or more is got out in one breadth, and worked away from the commencement to the extremity; also, that for the conveyance of coal from the working faces, tram-gates are made in the whole coal on each side of this breadth. I wish to know, father, if this is the only way of getting coal out in *bank* or *wide*

PLAN No. 10.



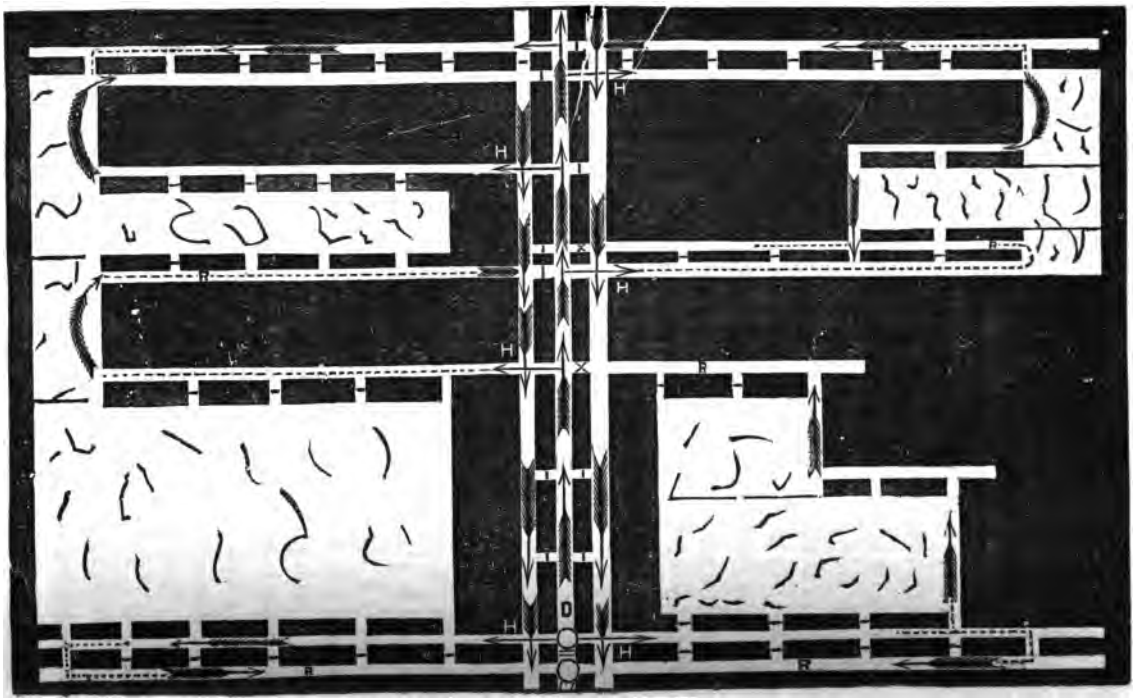
work?—Father: It is not the only way. In some mines only half is worked out at first, the other half being followed up a little behind it, or if the whole breadth is worked out, another breadth of, say 30 or 40 yards, follows up the first. You will see this mode of working illustrated in plan No. 11. Tram-gates for the conveyance of the coal are cut in the whole coal on each side of breadth worked out. The mode of ventilation represented in this plan is that of separate currents.

Son: Is there any other way by which coal is worked out in *wide work?—Father:* Yes, the following:—A great number of tram-gates are cut through on the seam end of the coal to the extremity of the block to be worked out, after which coal is worked away on each tram-gate backward to the pit eye. Now, as tram-gates are cut in this case on the "endway" of the coal, the coal is worked away in breadths between tram-gate and tram-gate,—that is, spaces of from 10 to 20 yards each in width are worked out between one tram-gate and another, on the face of the coal, until the whole is worked away backward from the extremity. You will see a representation of this mode of working out coal in plan No. 2, page 74.

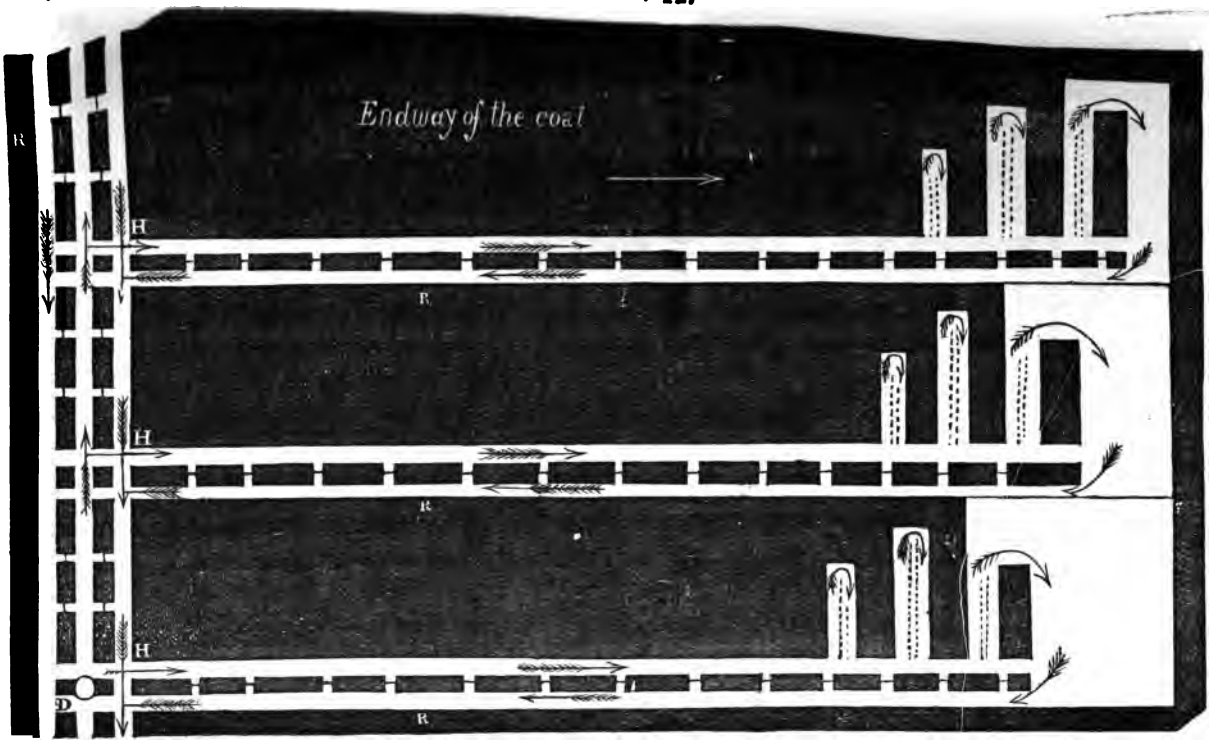
Son: I see by this mode, father, that as tram-gates are cut in the whole coal in plan No. 2 to the extremity, and worked back in wide places, the goaf will be left behind?—*Father:* Yes. This mode is often called "heading" or "ending" work, because narrow places are cut on the seam end of the coal, and not on the boardway of it, as in plan No. 11.

Son: Very good, father; but how is coal worked out in drifts? —*Father:* The mode is similar to that shown in plan No. 12, it being worked away in headings or endings. Narrow places are cut, as before, on the endway of the coal, after which blocks of

PLAN N$_0$. **11.**



PLAN No. 12.



coal from six to ten yards in width are worked out between one heading or tram-gate and another, a pillar or post of coal being left between two drifts; such pillars are worked backward (after the drifts are finished) to the tram-gate. For your better information I must refer you again to plan No. 12, as you will by it have a better knowledge of the said mode of working. The mode of ventilating the works is that of separate currents.

Son: What distance may these drifts be worked in from the tram-gates? and what width are the pillars or posts?—*Father:* The width of a pillar varies from six to ten yards or more, and the distance of drifts worked in also varies from ten to forty yards or more.

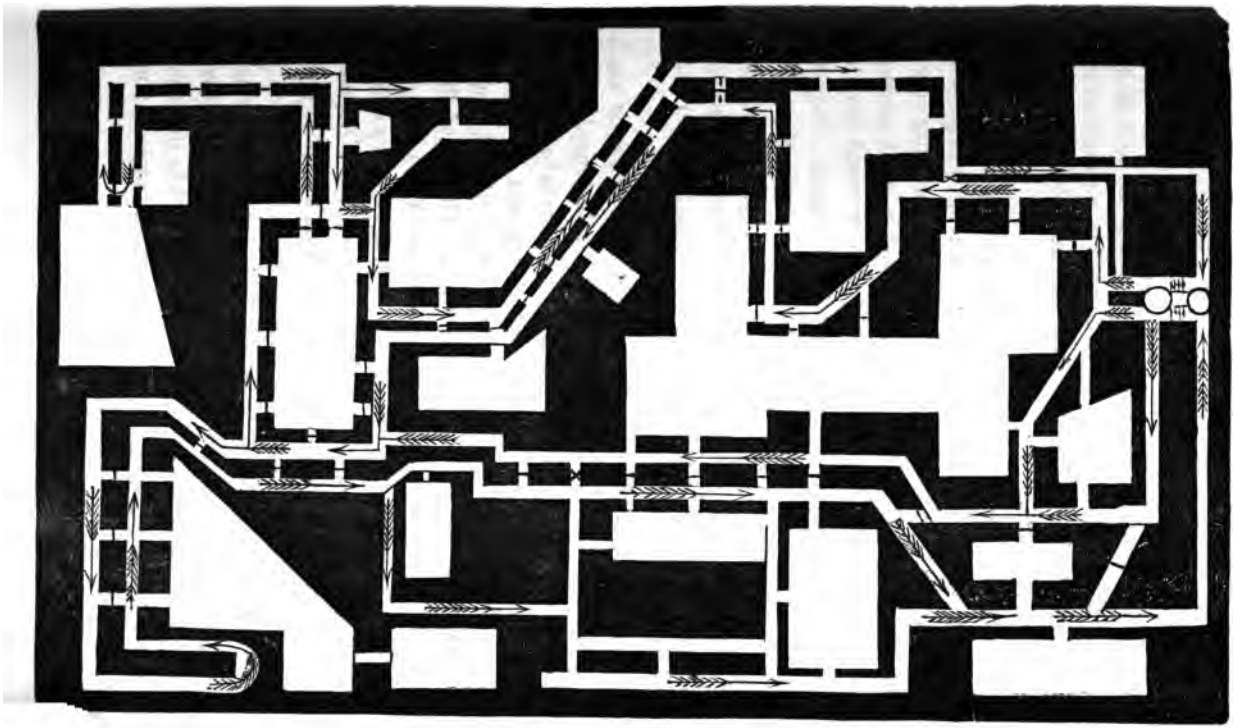
Son: Is there any other mode, father, by which coal is worked out?—*Father:* There are other ways of getting coal, but some managers have no regularity in their mode of working.

Son: In which way, then, do such managers work out the coal?—*Father:* They work it out from any place, anywhere, and in any way. Plan No. 13 will give you a better idea of this irregular mode of working out coal.

Son: What object do managers wish to accomplish by so working?—*Father:* They have several objects in view. One is to get a large quantity of coal, and produce a good profit for the employer. Another is to impress on the public and the employer's mind that they excel others in management.

Son: Is it not every manager's duty to get out a large quantity of coal, and try, if possible, to excel others in the management of mines, by which the employer may be profited?—*Father:* Yes; but if coal is not got out in a proper way, the profit produced will only be of short duration, as large blocks of coal are often left between two "goafs"; and, to work such blocks

PLAN No. 18.



out, there is always great expenditure and much loss of coal; and for the conveyance of the coal, roads of a circuitous route have often to be made, and many dangers met with, resulting often in loss of life.

Son: You know, and have seen, then, mines worked in the way you state?—*Father:* Yes, several; one colliery in particular, which would have been a good colliery for a number of years had it only been properly managed. It cost a great amount of money, but, after a few years, the proprietors would have been glad for any person to have taken it off their hands. They have since abandoned it, at a sacrifice of many thousands of pounds.

Son: Was the manager of the colliery in question a person who had a good knowledge of mines?—*Father:* He professed to have, as I know he took tradesmen's sons as pupils, to qualify them for underground managers.

Son: Is the manager still at the same colliery, or was he discharged?—*Father:* Discharged—no; he had produced too good a profit in the short time he had been there to be discharged, and it would have been impossible for any person to impress on the minds of the employers anything disrespectful of him; yet he knew better than to remain there when the inside of the pie was got out, and another colliery was offered to him.

Son: Then those who came to manage the colliery after him would not be able to make it pay so well?—*Father:* No, neither could he, had he remained there, have made the colliery pay a good profit afterwards.

Son: I think his pupils would obtain but little information in regard to the management of mines by such a mode of working?—*Father:* If a person intends to be expert in the management of the underground workings, he must be taught in a mine,

and not out of it; or he will have nearly the same knowledge of a mine as a mine would have of him. I have been in mines fifty years, and yet I find things in which I can profit constantly occurring.

Son: Are there no good, practical, and talented men to be found to manage the underground workings? and if so, is it not a mistake to place a tradesman's son in such an office?—*Father:* There are many practical men, and men of first-class knowledge, well able to take the management of the underground workings, but they are not always allowed to do so.

Son: Should not underground managers have a knowledge of the capabilities of the workmen under their charge, so as to appoint the right man to the right place?—*Father:* Yes, because some workmen have a better knowledge than others of gases, ventilation, fixing doors, overthrows, stoppings, bars, props, rails, laying and preparing roads, &c.

Son: I think they should also have a good judgment of every person's work, so as to give to each his right and due, and not to deduct the workmen's wages, as some, I fear, often do, as if good management consisted in that; but if they will show a good profit for their employers, let it be by excelling in real practical management.—*Father:* You are right; If a person can show his employer no profit but what he can take off a poor man's wages, the sooner he is removed the better; his object should always be to better the employed as well as the employer—to do right to all.

Son: Is not the work in mines often much better, and attended with more profit to the miner, in one part than in another?—*Father:* Yes; and such being the case, the manager ought to give every miner an equal share of this better work, as far as it is possible, and not give the whole of it to those persons who

may have obtained his favour by spending a convivial hour or two with him after the toils of the day or week. Fault-finders or tale-bearers generally have all the better work.

The best and most competent Persons to manage the Underground Workings of Mines.

Son: Who do you think are most competent, father, to manage the underground workings of mines?—*Father:* Those persons who have both a practical and theoretical knowledge of mining. Such managers have a double advantage, as their knowledge has been practically acquired. They cannot be equalled by any other class of men. Therefore, I would recommend every one in charge of mines to obtain a knowledge both of the theory and practice of mining.

Son: I think those in charge of mines, father, should be steady, sober, and attentive, having good knowledge, foresight, and stability, because mines are constantly changing, and things taking place which require much attention and care.—*Father:* Yes; a person should possess the whole of these qualifications before he takes charge of so many lives and so much property; he should be a man that will go first into a mine when an explosion of fire-damp has taken place. A good manager would not send others where he would not go himself; he will go first, and see the cause, and risk his own life rather than those under his charge, because others, not having a proper knowledge of their work, and the mode of ventilation, might not do right, from having too great a fear of doing wrong, by which they might cause the loss of their own lives, as well as those they were trying to save.

Son: It is your wish, I know, father, for every practical man who possesses the abilities to manage the underground workings of mines (as many practical men in mines, you say, have) to be brought out from the ranks, and for a mining institute to be formed, and that from such institute every one should pass an examination as to his qualification for underground manager. Would you, therefore, have every mining district to call out the men who have got a good knowledge of mining, and give them practical information on ventilation, gases, working out coal, surveying, and laying the workings on a plan, &c., such information being had in their own districts, after which they could be recommended for examination?—*Father:* Yes, I think it would be well for every district to have days for the men to meet to receive information in their own district, to qualify them, as the abilities of a person may be very good, but he may be too poor to attend often an institute which is at a distance from his own home. After the men have got to a state of efficiency, they should be recommended to some institute for examination.

Mine and Land Surveying.

Father: A knowledge of land and mine surveying, and also of planning, is useful for managers, they should understand its duties.

Son: I think so. Is this then a dial? (See next page.) *Father:* Yes; it is made by Casartelli, 43, Market-street, Manchester, with the latest improvement which has just been accomplished by him. Mr. Casartelli improved the miners' dial, by mounting the limb which carries the sights on axes or trunnions, cast on the compass box, attaching the arc for giving

Casartelli's Latest Improved Circumferenter, or Miner's Dial.

the angles of inclination to one of the trunnions, with the index so fixed as to be moved by the sight-limb whenever it was inclined to look through the sight up or down the road, thus giving the angle of *rise* or *dip*. This worked well, but it was necessary to take off the arc every time the dial was put in its case, and to fix it on the dial whenever it was required, and it sometimes happened that when wanted it was in the case in another part of the mine. To obviate this inconvenience, Mr. Casartelli recently introduced a semicircular limb, fixed to the compass box by pivots in the line of N. & S. in such manner as not to obstruct the view through the sights; the degrees of angle are graduated on the face of the semicircle, and read off by indexes attached to the sight-limb, and which ride over the face of the semicircle when the limb is inclined for the purpose of taking a sight in steep mines. When the arc is not required, it is simply folded down on the outside of the compass box, between the latter and the sight-limb. By this improvement the moveable quadrant is done away with and all its inconveniences; the present semicircular arc is always at hand when required, and it can be put in or out of use in an instant.

Son: I think such a dial is very convenient.—*Father:* Much so for mine surveying. The needle may be either used or not, and if dispensed with you can use the dial as a theodolite, and by it take the dip of the mine also.

Son: There are many kinds of dials, are there not?—*Father:* Yes; I will show you others, but I think the one just referred to is very useful.

Son: You say, father, underground managers should have a knowledge of mine surveying and to lay down the workings of a mine on plan. I wish to know how you would have them to

get this information, as few persons will show a miner intending to improve himself how it is accomplished, be his abilities ever so good?—*Father:* I know few persons will show a man with a practical knowledge of mines how to survey. It cost me a good sum of money, and I had much to do to induce a person to give me the information; also I have often had letters from practical men asking how to survey, and I have been sorry not to have been able to give them that information by letter that I could have done had I been in their company a short time; this knowledge is soon obtained by seeing and doing the work. It is difficult a little to understand by reading and hearing,*

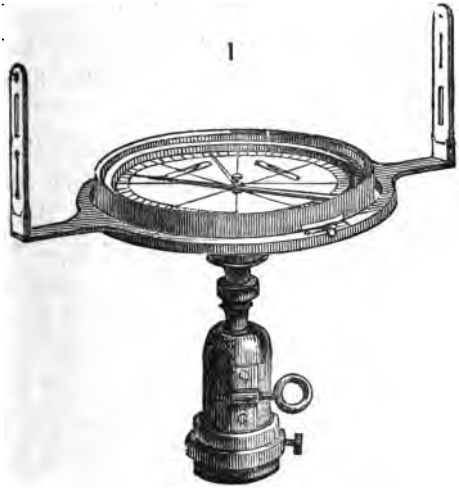
Son: Would it take a long time for a person to get the necessary knowledge?—*Father:* No. It would soon be obtained if those who wish to acquire it could only have a little practice.

Son: But I fear no one, father, would show a number of underlookers and deputies the way mines are surveyed; that is, they would not take the dial into a mine and show them.—*Father:* The information can be got on the surface; and a person would very soon understand how to survey in a mine, he having a practical knowledge of the underground workings.

Son: I should be glad to understand mine surveying and how to lay the workings on a plan, if you can give me that information.—*Father:* I hope to show you how to survey mines with both the compass and the theodolite, and also how to lay the workings of a mine on a plan, if you will attend to what I shall say, as I shall give an explanation of the figures on the dial.

* The knowledge of mine surveying and planning may be understood by reading this Conversation on Mines. Several persons have written to say that they are able to survey the workings of mines, and lay the same on plan, by reading the contents of this book. I might name two persons out of many, Mr. W. Hitchin, underlooker, of St. Helens; and Mr. Wm. Valentine, underlooker, of Wigan.

Son: Be assured, father, it will be my endeavour and delight to attend to your instructions, because I very much desire to know how to dial, and lay down the workings of a mine on a plan.—*Father:* The diagram you see is another representation of a dial; you look at objects through the upright sights.



Son: Is this then a dial? I see no figures on the dial plate. *Father:* You cannot see the figures in its *present form*, but I will show you it in another, to enable you to see them. In the large plan you will see the dial in another form; see No. 14, at the beginning of this book.

Son: Yes, father, I see the figures better now.—*Father:* Fig. No. 14 is a representation of the dial. There are, you see, figures "around" the outer circle which give the number of

degrees around its circumference. You will see, also, figures around the inner circle; these give the number of degrees between north and east; and also, between north and west. It likewise gives the number of degrees in the quadrant, that is, between south and west, and between south and east. For example, there are 360 degrees around the whole outer circle of the dial, but between north and west in the inner circle, there are 90 degrees. Also 90 degrees between north and east; 90 between south and west; and the same number between south and east.

Son: I see there are two rounds of figures on the dial plate; those figures around the whole outer circle show 360 degrees; but those around the inner circle show 90 four times repeated. *Father:* Yes; so that when you read off those 360 degrees around the outer circle of the dial you must make an entry of the number, whatever that number may be; but if you make an entry of the number of degrees between north and west, or between south and east, you will have to read off those degrees or figures around the inner circle of the dial, and give the number of degrees between north and west, &c., whatever that number may be.

Son: Are dials all figured alike?—*Father:* No. Some are figured round on the left-hand, similar to the dial shown in the large plan, fig. 14, others are figured round on the right-hand, similar to the figures on a clock face, commencing at 1, 2, 3, to 12, and so on to 360.

Son: If dials are not all figured one way round, protractors will not have to be figured all one way, will they?—*Father:* No. A protractor (to be suitable for a dial) should be figured round it on the opposite direction to the dial.

Son: Then if a dial reads off on the right-hand, a protractor should read off on the left to be suitable for a dial; but if a dial reads off on the left, my protractor must be read off on the right? —*Father:* Just so. If you attend to this you will soon survey with any dials.

Son: Very good, I understand the figures on the dial, but what about the dial needle? I see it vibrates, or works backward and forward at every turn or movement of the dial.— *Father:* The cause of the vibration of the needle is, that it is a magnetic one, which is balanced upon the point of a pivot, so that it can vibrate without friction towards the direction to which it is most attracted. Its tendency is always to point one end north and the other south. That is to say, the needle may vibrate backward and forward when the dial is removed, but it will soon come to a stand-still when the dial is at rest, and one end will point north, and the other, of course, south. We learn from observations that the needle does not always point to the same place; there is a slow, but almost continual variation, which does not appear to be capable of previous calculation. Thus, in the year 1576, the variation from true north was 11° 15′ east; in 1657, the needle stood due north; in 1803, there was a west variation of 24° 59′; in 1820, the variation was about 24° 12′ west, and from that time to August, 1864, the needle has varied to the east about 3° 40′. The variation in the beginning of 1868 was 20° 15′ W. Generally, it may be understood that the western declination is now diminishing at the rate of 1° in eight years. When the survey of underground workings is performed by the compass, it is well to have the meridian lines which are drawn on a plan dated, by which means the variation can be got, so that in every subsequent survey, if the variation

be different, the meridian used in plotting can be altered accordingly.

Son: Suppose, father, I take the dial, and fix it at any point I may think proper, and look at an object at a distance; how am I to fix the dial so as to obtain the proper degree north or south from the situation of the dial?—*Father:* Before I commence to show you how to fix the dial, and to understand its indications, I wish you to have a look once more at the dial. You see (on the large plan No. 14) a letter N next to one of the sights, and also a letter S near the other sight. Well, when you fix the dial, always have the sight N next to the object you look at, and look through the upright sight S. That is in going forward. If you fix a dial in a mine, see and always have the upright sight or letter N next to the working face, and the sight S next to the pit from whence you go, looking through the sight at objects which convey you from the pit into the workings, and so continue to look through at the letter S, sight after sight, until you come to the working face; but if you take a back sight at an object towards the pit, keep the dial in the same direction, looking through the upright sight letter N:—that is, keep the dial fixed so that the sight at the letter N will always point into the workings, and the sight at S towards the pit shaft.

Son: Very well; I am glad, father, for the information how to fix the dial. I thoroughly understand it now. But how am I to know the number of degrees between one object and another?—*Father:* You must fix the dial in the way just described, and look at objects through the sight S (if such objects convey you from the pit into the workings); after the needle has come to a stand-still, look at the north-end of the needle (as one end always, as before stated, points north, and the other south),

and note what degree the point of the needle is at, and whatever it may be, make an entry of it in your book, for it is the number of the degree away from the north to the object.

Son: Suppose the north-end of the needle should stand or point at 63½°, will it be 63½° north-east?—*Father:* Just so. The degrees are the same in this case as those degrees around both the outer circle and the inner circle of the dial, yet it is not requisite at all times to make an entry in your book of the two rounds of figures. I only give you a knowledge how to read off the dial by the two ways, so that, if required, you will be able to read it off by either way; that is, you will understand both the rounds of figures. Yet, as you are only a learner, you will understand the degrees of the dial much better if you make an entry only of the outer circle first.

Son: Then if I find the point of the needle stands at, say 63½°, when looking at an object, all I have to do is to make an entry of it in my book, which is 63½° to the object? But what am I to understand by these 63½°?—*Father:* Well, the point of the dial needle stands or points north, therefore, 63½° is so much away from that north point; that is, you will have turned the sight N away from the north point of the needle, that a space of 63½° will be between the north end of the needle point and the sight N.

Son: Then if I look at another object through the sight S, and the north-end of the needle point at 125 degrees, I have only to make an entry of the degree in my book and the distance between object and object?—*Father:* That is all you have to do. If, on looking at an object, the needle points at 152 degrees, it only shows a greater space between the sight N and the north point of the needle. And in like manner you may continue to

look at objects in several directions, and every object looked at may vary in the degree more and more until you come with the sight N round again to the north point of the needle. Therefore, an object at 152 degrees would be 28 degrees in the south-east direction, that is, it would point 28 degrees away from the south-eastward. And, in like manner an object at 240 degrees would point to 60 degrees in the south-west direction. If you look at an object at, say 320 degrees, the needle would point at 40 degrees in the north-west direction. There is no cause (as before stated) for you to bewilder yourself by making an entry in your book of the two rounds of figures, unless you think proper; the figures around the outer circle of the dial will do for one way of surveying.

Son: I think every person, father, may understand how to fix a dial, and also make a proper entry of the degrees, after being informed in this way. But how would you commence to survey the underground workings of a mine?—*Father:* Suppose you are required to survey workings similar to those on figure 15; you may make, if you think proper, a sketch in your book similar to figure 15, or according to the roads cut in the mine: after which, fix the dial in any part of the road, so as to see the centre of the pit and along the tram-road forward to the cross-roads. At the same time, let the dial be so fixed that the sight S will be next to the shaft, and the sight N next to the working-face, always keeping the dial in the manner described; then look forwards through the sight S, but if you have cause to take a back sight towards the pit, look through the sight N, and after the needle has come to a stand-still, make an entry of the degree pointed to.

Son: Suppose, father, I find the north-end of the needle point to 68½ degrees?—*Father:* If so, make an entry on the

sketch in your book, similar to the one you see on the figure; it shows 63½ degrees, so that it is 63½ degrees north-east. Afterwards measure the length from the pit to the cross-roads.

Son: Suppose the length of the road is forty-five yards? *Father:* Then mark forty-five in figures, similar to those you see on the sketch. (See large plan at beginning of book.)

Son: The length being put down, do I remove the dial forward to another object?—*Father:* Yes; and fix it, if possible, in the centre of the cross-roads, so that you may look forward into each side road without removing it; but, if you cannot fix it there on account of iron, which affects the needle, each road will have to be taken separately, in the way you took the first length from the pit.

Son: Suppose I fix the dial and look forward on the first road, and find the north end of the needle to point at 61 degrees, and the length from the cross-road to the end of the road is forty yards, and I look for the degrees on each side-road. One road I find at 152 degrees, and the other at 332½; all I have to do is to make an entry of the figures with the length of each road, one of the lengths being, say forty-five yards, and the other twenty-two yards.—*Father:* Just so. That is the way with the degrees around the circle, but those degrees of the quadrant will be north-east 61, south-east 28, and north-west 27½ degrees.

Son: Then the sketch in my book will be like figure 15?—*Father:* Just so. Now you have a knowledge of surveying, how to read off the dial; and if you only attend well to it, you are sure to know the direction of each working part of the mine, and be able to dial forward as the workings extend, from sight

to sight, until every sight is surveyed from the pit to the extremity of every road in the whole mine.

Son: As I have got a knowledge of surveying, I now wish to understand how to lay the workings of a mine on a plan; that is if I had a large sheet of paper, I wish to know on what part of the paper to fix the pit, and how to lay down the workings? *Father:* All you have to do is simply to place a mark on your paper similar to the letter O, and call that the pit; you may fix the pit on any part of the paper, but as near the centre of it as possible will be best.

Son: And what must I do, after fixing the pit?—*Father:* You see a line across the pit in figure 16, do you not? (See large plan.)

Son: Yes. I also see at one end of the line a letter N, and a letter S at the other end. The line crosses the centre of the pit. *Father:* Well, when you have fixed the pit on the paper, draw a line across it similar to the one you see in figure 16.

Son: I am quite able to do that, but what must I do after?—*Father:* Next take your protractor and place it across the pit and line, after which it will represent figure 17.

Son: Very well. I am able to do that also. I see figure 17 is only a representation of figure 16, with a protracter added to it; but what have I to do after fixing the protracter?—*Father:* You have only to look into your book (figure 15) for the degrees from the pit to the cross-roads. Did you not make an entry there of 61½ degrees from the pit to the cross-roads?

Son: Yes, the number of degrees are, I see (figure 15) 68½, and the length of the road is 45 yards.—*Father:* All you have to do, then, is to count round from the north end of the

protractor until you come to 68½ degrees, and there make a pin mark (see P) in the side of the protracter.

Son: After I have done so, must I then take up the protracter?—*Father:* Yes, and measure from the centre of the pit, forward in the direction of the pin point, the length of the road, 45 yards, on a scale of 20 yards to one inch.

Son: After measuring the length of the road, will it represent figure 18? as I see the road extends beyond the pin mark P.—*Father:* Yes, and by so doing you have got the pit, and the first length upon the plan.

Son: I see, I now want the cross-roads; what have I to do next to lay them on the plan?—*Father:* All you have to do is simply to make another line with your pencil across the end of the road, similar to the one across the pit. This line must be parallel to the one across the pit; to make a correct line you require a parallel ruler (See figure 19).

Son: Figure 19 is, I see, only a representation of figure 18, with a parallel ruler upon it, the ruler must be opened out until a line can be drawn across the end of the road. But what must I do after?—*Father:* You have to take your protracter, and again place it across the road, similar as you did across the pit (see figure 17).

Son: When I have done so, it will represent I see figure 20, as the protracter is upon the line N and S.—*Father:* Such is the case. Look again for the degrees in your book (figure 15); there are for one road 61, another 152, and the third road 332½; such are the several degrees along each road.

Son: Then, I presume, father, I have only to do as before, count round the protracter for the degree on each road, and make a pin mark at every degree?—*Father:* Just so. You count

round the protracter until you see 61, then make a pin mark at P, after which count again until you find 152, and there also make another pin mark at P. Count forward to 332½, and make another pin mark there.

Son: Very well; I see all the pin marks upon the edge of the protracter; do I now lift it off.—*Father:* Yes. You take off the protracter, it will then represent figure 21. See all the pin marks P.

Son: I think I see now how to plan: I have only to measure separately each road, measuring from the end of the road direct to each pin mark. The measurement of one road is forty yards, or two inches on the plan; the other roads are twenty-four yards and twenty-two yards.—*Father:* That is the way; make the length of each road according to the scale, and also according to the number of yards you have entered in your book.

Son: When I have got the length of each road on the plan it will be like figure 22.—*Father:* Yes, continue to lay the workings on the paper until the whole of them are finished.

Son: Is there any other way, father, to lay workings on plan?—*Father:* Yes, all you have to do, is to place the pit, as before, on your plan similar to the letter O, any part of the plan-paper will do, if only you have space enough for the workings, near the centre of it is the best. Also the meridian line should not be marked across the pit in this case, but marked on the paper in any part best suitable.

Son: If the pit be marked in one part of the plan, and the meridian line in another, how must I commence to lay down the workings?—*Father:* All you have to do is to place the protracter on the line similar to figure 25, page 156, after which mark off all the degrees entered in your book.

Son: The degrees entered, I see, in my book are as follows: 1st sight 90 degrees, and the length 11 yards. 2nd sight 80 degrees, length 8 yards. 3rd sight 50 degrees, length 14 yards. 4th sight 100 degrees, length 19 yards. I find the next sights point into another direction; because the 5th sight is 300 degrees, length 19 yards. 6th sight 345 degrees, length 33 yards.—*Father:*—Those are the lengths and number of the degrees named, therefore, if you look at the protracter (figure 25) you will see all the degrees marked, and in laying down the degrees of the roads in a mine they are marked round the protracter in a similar manner to figure 25, page 156.

Son: Now that the degrees are all marked, must I take the protracter away?—*Father:* Yes, take it away. See figure 26 with all the pin marks at each degree. Figure 26 is only a representation of figure 25, only the protracter is removed.

Son: I see all the pin marks: how must I lay down the workings?—*Father:* You know the first sight was at 90 degrees, and the length 11 yards.

Son: I do, and a pin mark is on the edge of the protracter at 90 degrees. This sight was No. 1, see it is parallel with A A, and the first length of the road from the pit.—*Father:* You are right, and so each sight is also parallel with the following numbers and letters, and each is also parallel with the degrees of the road. The second sight is also parallel with the letter B; the third sight is also parallel with the letter C, and so each sight is parallel with the road.

Son: Then all I have to do is to open the parallel ruler out, to make each degree parallel with the road?—*Father:* That is the way, and also to mark down the length of the roads between each sight.

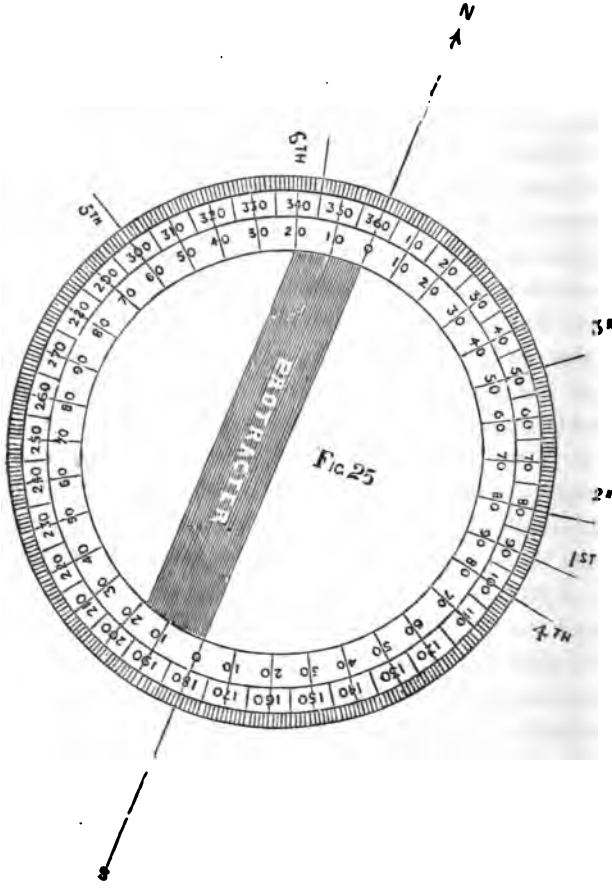
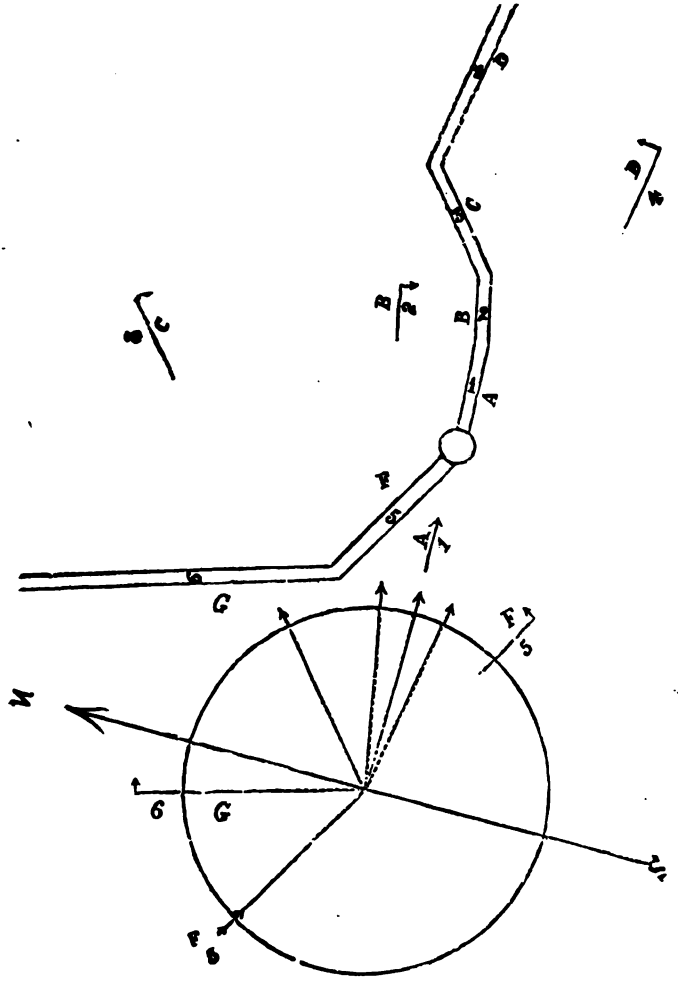


FIG 25

Figure 26.



Son: I see very well now, father, how to lay the workings down on plan by this mode of plotting. There is no cause to make a meridian line at the end of every sight, as you did by the other mode of plotting.—*Father:* No, the degrees entered in your book can all be marked off at once by this mode (See figure 26).

Son: I may, I presume, lay down fields, boundaries, &c., in a similar manner, if I only commence at the pit, and look towards such objects?—*Father:* Just so; you can lay on the plan any boundary or field, if only the pit or any well known object be the place at which you commence from; first lay down the pit on the plan, and therefore it must be the object to commence from to find others, or any other known object will do.

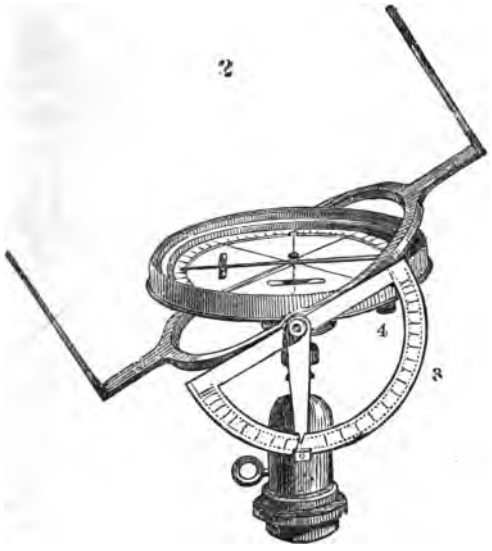
Son: I am very glad, father, for a knowledge of surveying, and also of laying the workings of a mine on a plan. I wish now to understand the way by which I may take the dip and rise of the mine?—*Father:* It is my intention to give you that information also. You see figure 23, on the large plan at the beginning of the book, which is a representation of a dial; on its cover there are figures similar to those in figure 23; you will also find in the cover two holes, as represented in figure 23. All you have to do is to fix a peg, as in figure 23, with a string and a weight suspended to it.

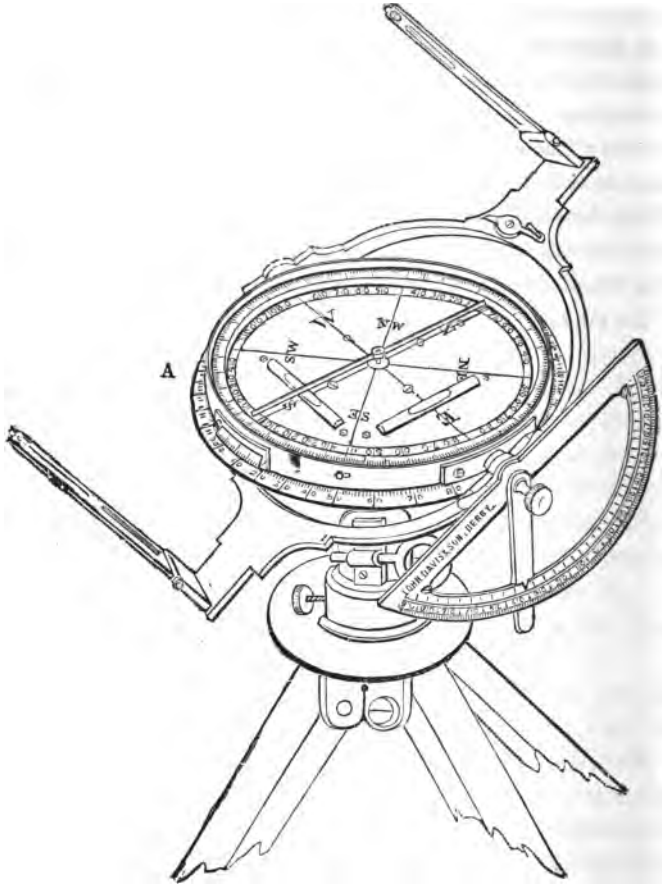
Son: Shall I have to fix the dial bent on one side, and look through the sights when it is bent down?—*Father:* Yes; and when you look through the sights at objects downwards or upwards, you will see the degree of such dip or rise of the mine.

Son: The string on the dial cover is at 17; do I understand the dip is 17 degrees?—*Father:* Just so. The mine dips at an angle of 17 degrees. All mines do not so dip; some more, others less; 17 degrees is about the dip in St. Helens.

Son: Do I lay the dip of the mine on a plan similar to the underground workings?—*Father:* Yes. All you have to do is to make a line on your plan, and call the line the level surface (see figure 24), place your protracter upon this line, and count round to 17, make a pin mark there, and then take up the protracter.

Son: The dip of a mine, I see, will be shown in the same manner as in the large plan, figure 24?—*Father:* Just so. You will understand now, how to take the dip and rise of the mine. You may take the rise and dip of the mine from another dial. (See the diagram.) It is so constructed as to suit the declivity of the mine.




A

Son: This dial must be very convenient. You will be able, with a dial like this, to take the degree of the road, and the dip or angle of it, at the same time.—*Father:* Yes; the dial is very convenient. It is Headley's dial, but manufactured by Mr. Davis, of Derby, the manufacturer of mining instruments.

Son: You have got here I see another of Mr. Davis's dials. (See page 160.)

Father: Yes. This dial is a very useful instrument, it combines all the latest Headley, with the outside vernier of the theodolite.

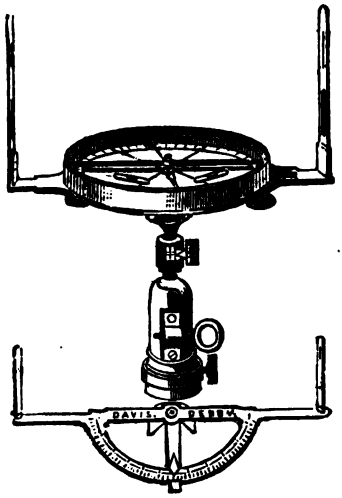
Son: This dial, manufactured by Mr. Davis, of Derby, is much improved, and also very useful for mine surveying.

Father: So it is. The figuring is so arranged that the readings of the needle and the vernier tally, thus keeping one another in check. If the needle be used, the vernier will detect the slightest local attraction, and that which has hitherto been doubtful in mining surveying will, with this instrument, be certain of accuracy as far as the magnetic bearings are concerned, which heretofore could only be checked by a repeated survey.

Son: The Headley sights and the vernier plate on this dial, may, I presume, be clamped, and the dial can then be used as an ordinary rigid one, can it not?

Father: So it can. One great advantage of this contruction is, that if the dial be out of adjustment, it is at once detected by comparing the vernier and needle readings.

Son: But in reference to its weight with others?—*Father:* Its weight is not more than that of the ordinary Headley, and it is equally compact. Here is also another form of dial, similar to Headley's, which are attached at pleasure, for ascertaining the angle or dip.



Theodolites for Mine Surveying.

Son: Is not the theodolite used now, father, for surveying the underground workings of mines?—*Father:* Yes; some people use such.

Son: Is the theodolite very difficult to understand?—*Father:* You may soon know how to use it for the surveying of mines, it is very simple.

Son: I much desire to know how to survey mines with the theodolite.—*Father:* It is my intention to give you that information also.

How Theodolites are constructed.

Son: I shall be glad to be informed how theodolites are constructed.—*Father:* I might give you a minute description

how several theodolites are constructed, but to do so would only bewilder you; therefore, my object will be to give the *principle* how they are constructed. Theodolites are similar to dials, with upright sights, through which you look at objects. Around the circular-plate are 360 degrees. The upright sights are so constructed that in moving them round, like the hands upon the face of a clock, you do not move the circular plate. Therefore, in moving round the sights to look through at an object, you take particular notice of the degree opposite the sights.

Son: I see, in my mind's eye, the principle upon which theodolites are constructed. The minute-hand on a clock face is moved round from the hour of twelve to one, and from thence to two, and forward round again to twelve. So also, are the sights on a theodolite moved round from 0 or zero; or from the north point on the theodolite-plate.—*Father:* I am glad you see the principle on which theodolites are constructed, you now require a knowledge how to use them.

The Magnetic Needle dispensed with, and how workings are laid on Plan by that Mode of Surveying.

Son: Just so, I wish to know that; but I would ask, is the magnetic needle entirely dispensed with in surveying mines by theodolities?—*Father:* The magnetic needle can be dispensed with entirely, if only the datum line can be found, that is, if you can find—say due north from the centre of the shaft—into any part of the workings; if not, you will have to use the needles the first length only, to find the direction from the pit-shaft into the workings.

Son: Well, but the underground tram-roads vary from a straight line; and if you dispense with the needle, how can you find the proper degree, or the proper direction from the pit into the workings?—*Father:* The degree of each tram-gate into the workings is very well found by the use of the theodolites. There are two ways by which mines may be surveyed with theodolites; yet the two ways are nearly alike. In both ways the workings are laid on a plan, just the same as when surveyed with the dial. The only difference in the one from the other is—you do not require to use the parallel ruler to make a meridian line at the end of every sight.

Son: I do not require to make a meridian line at the end of every sight; then how do I lay down the workings? Do I not use the protracter in the same manner as I used it in the other way of laying workings on a plan?—*Father:* You use the protracter.

Son: If I use the protracter, upon which line do I lay it, to find the next degree, or the angle of the road? because in the other mode of planning, I lay the protracter upon the meridian line.—*Father:* In laying the working down, so as to find the angle of each sight, you have only to place the protracter upon the line which you make from sight to sight; by so doing, you can find the angle of the following sight.

Son: I see very well, now, how this is accomplished. Each line of sight, or tram-gate-line, is similar to a meridian line, to find the next angle of the road.—*Father:* Just so. That mode of planning is adopted when you take the angle by one way of surveying with the theodolite, but not by the other.

How Mines are Surveyed by the Theodolite.

Son: I wish to know how to use the theodolite by the two ways, therefore; I think you may show the latter mode first.—*Father:* I will do so. I gave you a description of the theodolite, or the principle on which it is constructed; I wish you to bear that in mind. Then, suppose we take the theodolite into a mine, and commence to survey with it, from the pit along one of the tram-gates, into the workings. Again, suppose the first sight is due north from the pit, and the length of the first sight, say 100 yards.

Son: Well, say it is due north.—*Father:* If so, all we have to do is, to fix the theodolite in the tram-gate at the 100 yards mark, with the sights opposite 0, or north point (see page 166), and when so fixed, we must be able to see through the upright sights a light in the centre of the pit. After this, you move the sights round to look at another object at, say, 200 yards distance, in the direction of the workings, being very cautious not to move the theodolite plate in moving round the sights to the object.

Son: Suppose I find the degree 25 is opposite the sight, would that be at an angle of 25 degrees *from* the last sight?—*Father:* It is so. You now take up the theodolite, and again fix it at the end of the 200 yards mark, looking back at this 100 yards mark, being able to see a light through the upright sights, when such sights are opposite 0, or the north point on the theodolite plate. When the theodolite is fixed properly, and you are able to see the mark, you will have to move the sights round again, to see another object in the workings, at, say 300 yards distance.

Son: The degree opposite the sights, from this place to the 300 yards mark, is, I find, 15 degrees, or is it not at any angle

EXAMPLE.

The tram-gate from pit into working face.

The fourth sight, 400 yards in length, at an angle of 5 degrees from the third sight, or 45 degrees from due north.

The third sight, 800 yards in length, at an angle of 15 degrees from the second sight, or 40 degrees from due north.

The second sight, 200 yards in length, at an angle of 25 degrees from due north.

The first sight, 100 yards in length, due north.

of 15 degrees from the previous sight?—*Father:* Just so. You take up the theodolite again, and go fix it at the 300 yards mark, looking back also again to this 200 yards mark, being able to see it through the sights when such sights are opposite O, or the north point on the theodolite plate.

Son: I see, when so fixed, the upright sights are moved round again to look through at another object into the workings.—*Father:* So they are. Say the next sight is at 400 yards distance, and also at an angle from this sight of 5 degrees. And so you continue in like manner, from sight to sight, taking the angles as they vary from previous sights, until the whole mine is surveyed. My object is to give you the principle of the thing, and not to bewilder you with minutes, seconds, and thirds.

Son: As you have shown *one way* of mine surveying, with the theodolite, which I now understand, I shall be glad to be informed *how* the other is accomplished.—*Father:* Well, the first and second sights are taken just in the same manner as the two first sights were. The first sight, you know, from the pit was due north, and the second sight was at an angle of 25 degrees, looking at an object in the workings 200 yards distant. All that is required then, is to fix the theodolite at the 200 yards mark, and look back (as before) to the 100 yards mark, and in looking back through the sights, you must not fix the sights opposite O, or the north point on the theodolite plate, but fix them opposite degree 25. When you have got the degree properly, with the sights opposite 25, then you move round the sights to look through at the other mark at 300 yards distance. After so doing, you will find the sights opposite degree 40,—the direction of that sight being 40 degrees away from the north point. Then you again remove the theodolite to

the 300 yards mark, and look back also again to this mark, and in so looking back the sights must be *opposite* degree 40—the same being the degree of the road; and also, when found, it is the guide by which you know or find the degree of the next sight.

Son: After the theodolite is so fixed, are the sights removed round so that you may see the next object?—*Father:* So they are. The object is 400 yards, you know, from this one.

Son: I find the object at the 400 yards mark from here is opposite the degree 45.—*Father:* Such is the case. Do you not remember the sight, when taken by the other way, was at an angle of 5 degrees. What makes it 45 degrees is, because the 5 is added to the other 40 before; therefore, it is 45 degrees from the north point, or away due north 45 degrees, that is—25+15 =40+5=45. (See page 166 for example.)

Son: Then, if I fixed the theodolite again, and looked back, the sights must be opposite degree 45; after which I look forward to another sight, to see in what direction the road varies from the last one.—*Father:* Just so; and so in like manner you take *back sights* alternately, sight after sight, until all is finished. By this mode of surveying, you lay the working on plan just in the same manner as if surveyed with the dial.

How to find the degree of any Tramgate or road in a mine intended to be driven.

Son: I wish to drive a road from the pit to a certain place or object; how, father, must I find the degree to that object?—*Father:* Make a line on your plan from the point you wish to commence at, and from there to the object you intended to drive to; then carry the line parallel to the meridian line; lay your

protracter then on the meridian line, after which count round from the north of the protracter until the parallel line of the intended road crosses it, and where the line crosses the protracter, it is the degree of the intended road you require.

Son: When I have carried the line of the intended road parallel to the meridian line, and laid down the protracter upon it, if I find the line of the road crosses the protracter at, say 250 degrees, then I shall have to fix the sight of the road with the dial at 250 degrees?—*Father:* Just so. That is the way.

Miscellaneous Questions.

Son: I have a few questions to ask, which no doubt, you will try to answer.—*Father:* What are they?

Son: I wish to know how you find the area and the cubic contents of a circular pit?—*Father:* I do it in the following manner:—Measure across the pit or circle, and multiply the distance or diameter by itself; multiply again by ·7854, and then strike off the four last figures of the result in the manner below described. Find the area and also the cubic contents of a pit 12 feet in diameter and 365 feet deep.

Example.

To find the area and contents of a circular pit.

The diameter of pit	12 feet
Multiplied by itself	12
	144
Again multiply by	·7854
	576
	720
	1152
	1008
Area of Pit.....	113·0976 *Carried forward.*

Thus the area is nearly $113\frac{1}{10}$ feet.

Area of pit	113·0976	Also the cubic contents are $41,280\frac{6}{10}$ feet.
Multiplied by depth of pit	365	
	5654880	
	6785856	
	3392928	
Cubic contents	41,280·6240	

Son: I may find the cubic feet, then, of any circular pit, or circular air passage, by this mode, be it less or more?—*Father:* Yes, you will have to adopt this mode of measurement, whether the diameter be in inches, feet, or in yards. If the diameter of the pit had been 12 inches, and the depth 365 inches, there would have been the same result, but in inches, instead of in feet. To find the cubic contents of an air-passage not circular, multiply the length of it by the width. Thus the length of the passage may be, say sixty feet, by five feet wide and four feet high. $60 \times 5 = 300 \times 4 = 1200$.

According to the late Dr. Glover, 666 cubic feet of air will sustain a healthy man for twenty-four hours: if so, an air-passage of 1,200 feet would, if full of pure air, sustain a man forty-three hours. One man inhales 135 gallons of air every hour; a pony 540 gallons; a horse 1,080 gallons.

Son: I wish to know the rule by which to find the area and cubic feet in the sinking of a pit, of any diameter and depth.—*Father:* I will show you how to find the area, cubic feet, and also what number of bricks is required in the walling of a pit.

Son: Such information will be very valuable. It will show how to calculate the amount of labour in sinking a pit.

To find the area and cubic feet of a pit 13 *feet diameter.*

Diameter 13 feet, multiplied by 13=169, multiply again by ·7854=132·7826, multiply now by 1521, the supposed depth of

pit=201886·2846, total number of cubic feet.—*Father:* You see the rule in the table, on the opposite page, how to find the area and cubic feet of a pit. Multiply (as you see) the diameter by itself, then multiply 169 by ·7854, and strike off the four last figures, the remainder (132) being the area of pit.

Son: Why strike off the four last figures? Do they count for nothing?—*Father:* The figures you strike off are decimals, that nearest the decimal point representing tenths, the next hundredths, and so on. Seven, you see, therefore is seven-tenths of a foot, or a little more.

Son: How are the cubic feet of a circular pit ascertained?—*Father:* Just in the same manner as you see in the table. Multiply the area of the pit by its depth; and again strike off the decimals, and the remainder is the result in the cubic feet (201,886).

Son: Give me the rules, now, how to find the circumference of a pit (say 13 feet diameter), and the number of bricks required to wall one.—*Father:* The following rule in mensuration will enable you to find the circumference of anything circular, whatsoever the diameter may be.

Multiply.....	3·1416
By, say a 13 feet diameter pit...	13
	9·4248
	31·416
	40·8408

Thus, you see the result as seen in the table.

Son: There are, I see, four decimals also in this.—*Father:* Yes; four is the number,—circumference of pit $40\frac{8}{10}$ feet.

Son: How do I find the area then, father, in feet to be walled?—*Father:* By multiplying the figures which show the

circumference, by the depth of pit to be walled. Supposed depth 521 × 40·8408=21,278·0568 area to be walled. Again the number of bricks in a foot=5·333 × 21,278·0568,= 113475·8769144. This gives the total number of bricks in the walling of a pit at the supposed depth of 521 feet.

Son: Are there not, father, three more decimals added to the others, which make seven?—*Father:* Yes, 333 are decimals, which are equivalent to one-third of a brick. If a brick is nine inches in length, and three inches in depth, it will require five bricks and a third to wall one foot area.

Son: I am glad for the information. I think I am able to find the cubic feet, &c., of a pit.—*Father:* Here are a few tables for your information, in which you may practice.

To find the area and cubic contents of a pit 13 feet 3 inches diameter. Diameter, 13·25 feet by 13·25=175·5625. Multiply again by ·7854=137·88678750. Multiply by 3212, supposed depth of pit,=442892·36145000, the total number of cubic feet in shaft.

We will find the circumference of a 13 feet 3 inches diameter pit, and the number of bricks required to wall one this diameter. Multiply 3·1416 by the diameter, 13·25, to find the circumference of pit=41·626200 feet. Multiply 41·626200 by 1212, the supposed depth of pit,=50450·954400 feet, area to wall. Multiply 50450·954400 by 5·333, the number of bricks per square foot,=269054·939815200, the total number of bricks required.

Now we will find the area and cubic contents of a pit 13 feet 6 inches in diameter. Multiply the diameter, 13·5 feet by 13·5 feet=182·25, the sum of diameter multiplied by itself. Multiply 182·25 by ·7854=143·139150 feet area of pit mouth. Multiply

148·139150 by the supposed depth of pit 2315=331367·132250, total number of cubic feet.

Find now the circumference of a 13 feet 6 inches diameter pit, and number of bricks required to wall one of the same diameter. Multiply 3·1416 by the diameter, 13·5=424·1160 feet circumference of pit. Multiply 42·41160 by the supposed depth of pit, 1232=52251·09120 feet area to wall. Multiply 52251·09120 by number of bricks per square foot, 5·333=278655·06936960, total number of bricks required.

We must now find the area and cubic contents of a pit 13 feet 9 inches diameter. Diameter, 13·75 by 13·75=189·0625, feet, sum of diameter, multiplied by itself. Multiply 189·0625 by ·7854=148·48968750 feet, area of pit mouth. Multiply 148·48968750 by supposed depth of pit, 3322=493282·74187500, total number of cubic feet.

Also find the circumference of a 13 feet 9 inches diameter, pit, and the number of bricks required to wall one of the same, diameter. Multiply 3·1416 by the diameter, 13·75=43·197000 feet, Multiply 43·197000 by supposed depth of pit, 3322= 143500·434000 feet, area to wall. Multiply 143500·434000 by number of bricks per square foot, 5·333=765287·8145222000, total number of bricks required.

Son: Any person able to add a few figures together, may, I think, understand the tables.—*Father:* My object is to make you understand all I say.

Son: Have you any knowledge, father, of what power is produced when a quantity of gas is ignited? That is, do you know what gas is capable (in proportion to its quantity) of propelling before it?—*Father:* I know the power of gas, when ignited, is very great, as may often be seen in mines after explosions. At

the Hetton colliery explosion, December 20, 1860, it was supposed that the explosion had been caused by a flue, containing about 7,000 cubic feet, becoming filled with gas, which afterwards ignited. The scientific evidence given by Mr. Isaac Lowthian Bell, and Dr. Thomas Richardson, was this:—Supposing the 7,000 feet to be exploded, it would become 56,000 feet, which would immediately be converted into after-damp. The temperature of these exploded gases being about 1,500 degrees Fahrenheit, or a bright red heat, the power would be equal to 75 quarter casks of gunpowder, of 25lbs. each; that is, an explosion of 1,875lbs. of gunpowder. So you may judge by this of the power of an explosion.

Son: Is blasting coal with powder allowed in mines where safety-lamps are used?—*Father:* It is allowed in some mines.

Son: Those who allow blasting know well, I presume, that explosive gas (carburetted hydrogen) cannot ignite at the flash of powder?—*Father:* Touch-paper is used for lighting with.

Son: Touch-paper is used. That is not the question. Will not explosive gas ignite at the flash of powder, where blasting is allowed?—*Father:* If explosive gas ignites at either a naked light or safety-lamp, so also will it ignite at the flash of powder.

Son: You know it will, then?—*Father:* To be sure; and persons who think otherwise I envy not their knowledge.

Son: Do not people say explosive gas cannot be destroyed?—*Father:* Yes; but it is well known to many, that gas in a stocked place has often exploded in the safety-lamp, and that after such a place has been filled with tobacco smoke, naked lights have been used. If the quantum of gas be above the explosive mixture, the gas will extinguish the tobacco in the pipe.

Son: Suppose much air passes around the place where a miner is working, is he to know by this that his place is safe from explosions?—*Father:* No; unless his knowledge is such as enables him to know the purity of the air; as the safety of his place is not in proportion to the quantity of air, but to the purity of it.

Son: If the same quantity of air passes around his place every day, is he to know by this that his place is safe from explosions?—*Father:* No; his place may not be safe then, because a change of the weather will cause a larger discharge of gas at one time than at another; and if a larger quantity of gas be discharged, the air will be more impure at such times.

Son: But suppose the miner can only see a little gas in the air which passes around his place; can he then know it to be safe?—*Father:* No; he cannot then say his place is safe, unless he has a knowledge of the several degrees of the impurity of the air: because, if gas be pure, very little will be seen before it explodes; therefore, he should have a knowledge of the quality as well as the quantity of the gas, to have a proper knowledge of the safety of his place.

Son: Suppose you had two pits, father, one say of 126 feet area, and the other only 100 feet area, which of the two, the the larger or the smaller, would you make into an upcast?—*Father:* The larger one, because the air expands on account of the heat of the furnace, and the high temperature of the mine, in passing through the workings to the up-cast; and also from gases being added in the air from the strata, space is required in the shaft for such expansion, otherwise, the velocity of the air in the up-cast would be greater than in the down-cast; and if the volocity be greater, the friction would be

greater; the said quantum of air cannot ascend up the shaft as it would do if the shaft were larger in proportion to the expansion of the air, because the friction would impede the ascent of the air, as a weight to a balloon would impede its ascent: for air is not propelled upwards out of a mine, but ascends like a balloon of itself—the ascent of the air being in proportion to its diminished lightness caused by its expansion.

Son: How much do you say air expands by heat?—*Father:* 480 parts of air, at 33 degrees of heat, become 481 parts, and increase one part for every additional degree—so that when the volume of air becomes increased to 600 parts, the temperature is then at 152 degrees. Therefore, suppose the down-cast air at a temperature of 32 degrees, and the up-cast air at a temperature of 152 degrees—the volume of air in the up-cast would have become expanded to 1-5th larger than the down-cast air; and if 1-5th expanded it would be 1-5th less in weight, in the space first occupied.

Son: Suppose the seam of coal in the workings should dip or rise, would the furnace produce more air, if the up-cast was fixed in one part, than it would in another?—*Father:* The same power of a furnace would produce more air if the up-cast was fixed in an elevated position: because, as before stated, the air expands in passing through the workings; and this being the case, its tendency is to ascend and not descend. It therefore follows that if a furnace be fixed where the shaft is in an elevated position, so that the air in passing through the workings may ascend and not descend, it will produce a larger quantity of air than one of the same power which is not fixed in such a position; because in a furnace so fixed, the air will assist the furnace, as it ascends through the mine to the up-cast, but will not do so if

it has to descend in passing to the up-cast. You may cause air to descend contrary to its nature, just as two horses might be pulling against each other; the strong one would pull away the weaker; so, in like manner, a larger furnace than needful would be required.

Son: Do you know what quantity of air is produced in mines per minute ?—*Father:* The quantity is not alike in all mines, but in some more, and in others less. The following will give you a knowledge of what has been produced in some mines.

DURHAM	Hetton Colliery		190,000	cubic ft.	per min.
NORTHUMBERLAND	Wallsend	do.	120,000	,,	,,
YORKSHIRE	Ardsley Main Colliery		80,000	,,	,,
,,	Lund-hill	do.	50,000	,,	,,
DERBYSHIRE	Speedwell	do.	40,000	,,	,,
*LANCASHIRE	Sutton Heath	do.	80,000	,,	,,

Son: Is not the quantity of air which rushes through and around the workings of a mine measured by the anemometer ? *Father:* Yes, it is one way of measuring it.

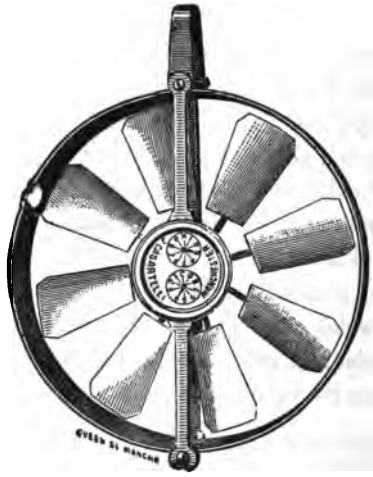
Son: Have you seen the anemometer ?—*Father:* Yes; it was invented by Mr. Biram, and manufactured by Mr. John Davis, Optician, Derby; and also by Casartelli, of Manchester.

Son: How is a person, father, to ascertain by the anemometer the number of cubic feet of air which rushes through the air passage ?—*Father:* In the following manner. The registering apparatus is in front of the wheel, and consists of six small circles marked respectively X, C, M, XM, CM, and M, the divisions on which denote units of the denominations of the respective circles; in other words, the X index in one revolution passes over its ten divisions, and registers (10×10) or 100

* This quantity of air was produced by one furnace 4 feet by 6 feet, and one up-cast of 9 feet diameter.

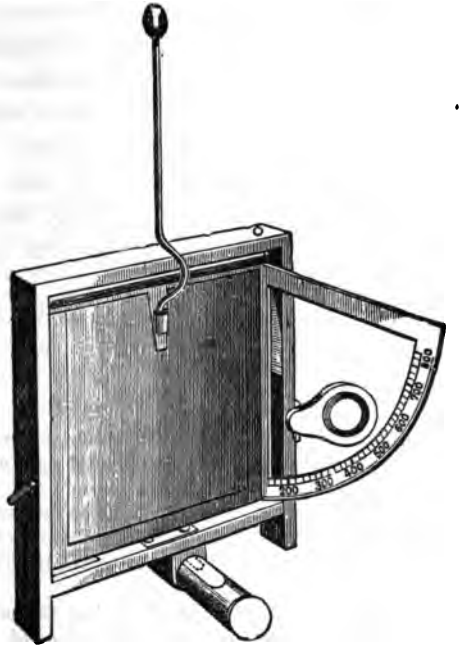
feet; the C index, in the same way, 1,000 feet; and so on, up to 10 million feet; so that an observer has only to record the position of the several indices, at the first observation (by writing the lowest of the two figures on the respective circles between which the index points in their proper order), and deduct the amount from their position at his second observation, to ascertain the velocity of the air which has passed during the interval; this multiplied by the area in feet of the passage where the instrument is placed, will show the number of cubic feet which have passed during the same period. These anemometers have been much improved recently by Mr. Casartelli, of Manchester, and are made by him.

Casartelli's improved Biram's Anemometer.



Son: Suppose I fix the anemometer further in the air-gate, and the number of revolutions be, say 1,000 feet; all I have to do, then, is to multiply the area of the passage by the 1,000 feet? *Father:* Just so. Suppose the area of the air-gate be 16 feet; multiply 16 by 1,000, and the result will show 16,000 cubic feet of air, which has passed in the space of time you have had it fixed—may be in a minute.

Casartelli's Dickenson's Anemometer.



DIRECTIONS FOR USE.

Place the instrument perpendicular by the Level. The figures on the Quadrant to which the Fan is raised, shows the velocity in feet per minute: the velocity thus ascertained, multiplied by the area, gives the amount of ventilation in cubic feet per minute.

Father: This anemometer was suggested by Joseph Dickinson, Esq., inspector of mines, and was arranged and made by Mr. Casartelli, of Manchester. It is much used by underlookers and deputies. No time for starting and stopping it is required, only to note the velocity of the current, which is marked on the quadrant.

Son: Nos. 200, 300, 700, &c., I see on the anemometer. If the force of the air current should send the fan up to 700, this would show the velocity of the current to be travelling 700 feet per minute?—*Father:* Just so, and that velocity multiplied by the area of the passage would give the quantity of air per minute. Sometimes the current will be intermittent, and the fan will move between two figures or divisions; in this case take the mean between the two figures as the velocity indicated. For example,—suppose the fan moves between 300 and 400, the velocity will be 350 feet per minute.

Son: Is there any other kind of anemometer?—*Father:* Yes, here is another by Mr. Casartelli, 43, Market-street, Manchester. (See next page.)

This anemometer (says Mr. Casartelli) is much recommended for its portability and great accuracy. Owing to the lightness of its construction, the error due to friction is reduced to a minimum.

In using the anemometer, it may be placed on a stand, held in the hand by the bottom, or on a rod fitting in the socket which accompanies the instrument, and which screws into the bottom of it. The Fan always to *face* the current.

The instrument is mode with *two* or more circles; the outer circle with the long pointer, represents *units*, and the others are *hundreds, thousands,*

tens of thousands, hundreds of thousands, and millions. Each circle is figured 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, which mean one, two, or three hundreds, or thousands, &c., according to the circle. Suppose the unit or long hand pointed to 40, that of the hundred circle to 3, of the thousand circle to 7, of the tens of thousands to 9, of the hundreds of thousands to 6, and of the millions to 4, the reading would be 4,697,340.

In taking a measurement, blow the fan until the large hand points to 0, then put down the *present* reading of the various circles, and after it has run one minute or other length of time, you take a second reading. Subtract the *first* from the *second* reading, the difference will be the velocity per minute, or per hour, or per day, according to the length of the running.

In order to *start* to time, and *stop* to time, there is a *stop* on one side of the rim outside of the face of the instrument which can be put off (say at 60) by the minute hand of the watch, and put on at the end of the minute so as to get the exact running in the minute without stopping the Fan.

Always be careful not to bend the fan or injure it, as it is so light.

Hall's Anemometer.

Son: You have explained to me the methods of measuring air by the "Biram" and "Dickinson" anemometers; are there any others to which you wish to call my attention?—*Father:* Yes. Mr. Hall, H.M. Inspector of Mines, has recently invented an anemometer by means of which it is possible, not only to measure the air passing through a colliery, but also to register the quantity from hour to hour, so that any change or variation of the current can be seen at a glance, and since this instrument also registers the speed of the ventilating fan, and also the water-guage pressure, the cause of any such variation can be detected.

Son: Tell me, father, how this anemometer you refer to operates, because it appears to be a great improvement on those you have already described?—*Father:* Attempts have often been

made to obtain a self-registering anemometer which would bear the wear and tear of constant work, but the dust and damp always present in the airways of mines quickly wore out such instruments; you can easily understand that such an anemometer as "Biram's," if fixed permanently in a great velocity of wind, would soon fly to pieces; indeed, all instruments with revolving or moveable parts are unsuitable for such a purpose. The "Robinson" anemometer, which consists of four semi-circular cups placed at the end of arms at right angles to each other, is the only one of the moveable anemometers which has been tried with any success. This "Robinson" anemometer does not revolve so rapidly as a "Biram," travelling theoretically at only one-third the speed of the current, whilst the "Biram" travels nearly as quick as the current itself; so that the wear and tear of constant motion in the former is somewhat less, but although this is so it has been found impossible to keep it in order for any length of time. Mr. Hall's new anemometer has no moveable part, it consists simply of hollow tubes of brass or iron converging at both ends to a small diameter in the centre, like two truncated cones joined together at their apexes; these are called venturi tubes, and when a tube of this form is presented with one of its large open ends to a current of air, the air as it passes through travels much quicker at the narrowest or smaller diameter of the tube, in precisely the same way as it does through a small regulator in an air-way underground, and this quickened speed causes a certain amount of vacuum at the point in the tube where it occurs, that is, it has a tendency to pull or drag anything after it in the same way as a railway train dashing through a station, catches up any light pieces of paper lying about, and carries them forward for some distance in its wake. Advantage

is taken of this peculiarity to measure the speed of the current passing through the tube in the following manner:—A small pipe is inserted into the narrowest portion of the tube, and this is connected with an ordinary water guage, and it is found that the water stands in one leg a certain height above the other, in exact proportion to the amount of vacuum set up by the speed of the air passing the tube at the narrowest part, and as the speed of the current increases or decreases, so the water rises and falls. Then by experiment certain heights of the one leg of water above the other are found to represent fixed velocities, and having got the velocity in this way, the total quantity of air is computed as with any other anemometer. With a single tube as described a velocity of current equal to one thousand feet per minute will show a quarter of an inch of water guage; and when a second tube of smaller size is inserted within the first, the registration increases to one inch; and on a third of still smaller size being introduced, the registration amounts to about four inches, although the speed of the current still remains at one thousand feet per minute. The rapid increase in the elevation of the water on the second and third tube being introduced, arises from the fact that the exit ends of these latter terminate exactly where a partial vacuum is already existing from the action of the first tube, the one thus assisting the other and causing the air to travel at a very high speed through the smallest tube, and thus a much greater vacuum is formed, and the amount of such vacuum is shown by the water guage.

Son: How does the water-guage show the vacuum set up in the smallest tube?—*Father:* The small pipe to which the water-guage is attached, is passed through the outer tubes, and is inserted

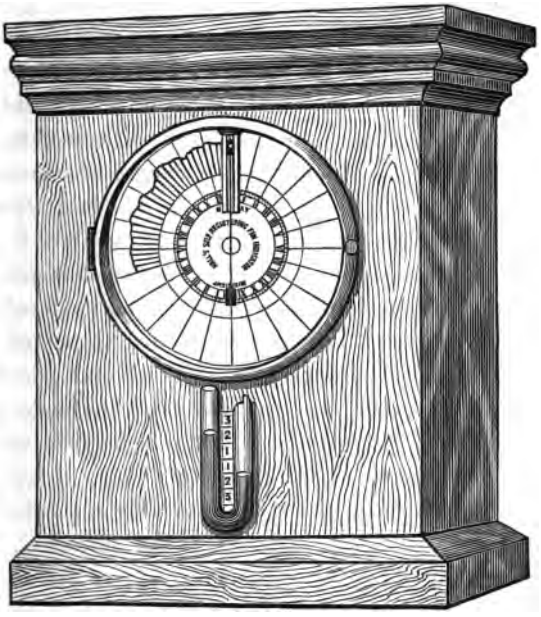
into the smallest or innermost tube, at the point where it is narrowest, that is, at the point of smallest diameter.

Son: I understand; and as you have explained that the exit end of each smaller tube terminates where a partial vacuum already exists, through the action of its predecessor, it is easy to understand that the same pressure of wind beating against the entrance end of the smallest tube, will cause air to rush through at a greatly increased speed, because of the exit end of the tube being in a partial vacuum as stated.—*Father:* Yes, quite so, this arrangement of the Venturi tubes was contrived by Mons. Bourdon, of Paris, and when used in conjunction with the self-registering apparatus, invented by Mr. Hall, it affords a reliable means of detecting any variation in the quantity of ventilation passing through a colliery.

Son: Does Mr. Hall's apparatus depend upon electricity?—*Father:* No, it is found that electricity is troublesome, and he adopts a much simpler plan. The small tube which I have already mentioned as being put in connection with the anemometer, is prolonged or extended to some convenient place, such as the manager's office, and the rise and fall of the water is made to move a marking pencil over a dial, kept in motion by clock-work, and thus a diagram is traced, showing the strength of ventilation at any hour of the day or night.

Son:—Yes; I understand, but you said that the instrument also exhibited the speed of the fan.—*Father:* That is so; a little valve is placed in the pipe, and at every five-hundredth revolution of the fan engine this valve is opened for a few seconds, allowing outside air to flow into the pipe, and causing the water guage to fall to zero for an instant, and each time that this occurs a downward stroke is marked on the diagram.

Son: Are there any of these instruments in practical operation at collieries ?—*Father:* Yes ; there are several working successfully.



HALL'S SELF-REGISTERING VENTILATION INDICATOR, MANUFACTURED BY JOHN WOODS, CLOCK AND SCIENTIFIC INSTRUMENT MAKER, RAINHILL, LANCASHIRE.

Son: I thank you for the information, father, on mines. I had no idea our conversation would have continued so long, and yet I am glad it has done so, I have more information now than I had before, for which I am thankful.—*Father:* My object is to do all the good I can. I take a pleasure in doing so—in putting,

if possible, the right man in the right place; in helping those who cannot help themselves; and in giving knowledge to those who require it. You have got a knowledge of gases; how mines discharge gases; why one discharges more gas than another; the cause of some mines discharging a mixture of gases; how it is that a change in the weather affects the workings of a mine; the power of an explosion, and how to diminish that power; how air is propelled down and around the workings of a mine; several ways of ventilation; the danger of one and the safety of another; the friction of the air in mines; the great friction produced by one mode of ventilation, and how it can be reduced by another; several ways by which friction is produced; the power of the furnace, and the quantity of air produced by an increased power; several ways by which coal is worked out in mines; why so many ways are adopted; and also who are the best and most competent persons to manage the underground workings of mines; of surveying and also laying the workings on a plan. I must now, my son, draw to a close. I hope what I have said you will inwardly digest, so that my labour bestowed upon you will not be in vain. If I have been successful, I shall be well rewarded, my object being to give you and all others information on this subject. My wish is, if ever you have charge of underground workings that you should do that which is right as far as is in your power, both to the employer and the employed. Give to every person his right and due. Do not give away your master's money, unless you have labour equivalent for it, as his money is not yours. Neither give away the workmen's labour to the master, for by so doing you rob them of their rights and living. Do to each as you would wish each to do to you. Study to be upright in all your dealings with every person, remem-

bering that life is only of short duration, so that you may be found right for the life to come.

Son: It is your will, I know, father, for me to do what is right and just, and I hope it will always be my endeavour so to do; if not, I may expect to be beaten with many stripes.— *Father:* If all people go astray, you are not justified in doing wrong. Never take advantage of a person because his profession of religion be not the same as yours; if he is sincere in his worship, look upon him as a friend and brother.

QUESTIONS AND ANSWERS

WRITTEN FOR THE ASSISTANCE OF THOSE INTENDING TO

COMPETE FOR CERTIFICATES

FOR THE

MANAGEMENT OF COLLIERIES.

Examiners: We presume you to be a steady, sober, and attentive person.—*Applicant:* I have not had any intoxicating drinks for years.

Examiners: Can you show any proof of your sobriety and attentiveness?—*Applicant:* I have a note here from my employer, whom I have served for years, one from the manager of the colliery, and another from our minister; and I have also a temperance certificate.

Examiners: You have had a situation, no doubt, in mines?—*Applicant:* I have worked my way up from a fireman to a deputy, and from a deputy to an under-viewer or under-looker.

Examiners: Are you, then, a thorough practical man?—*Applicant:* My experience in mines began in early life.

Examiners: Have you a knowledge of mathematics?—*Applicant:* A little; but I am self-taught.

Examiners: You have some knowledge, we presume, of decimals and fractions, &c., &c.—*Applicant:* Yes. My knowledge

of figures will enable me to measure, I think, anything required in the management of mines,

Examiners: You will be glad to give us, no doubt, a proof of your knowledge?—*Applicant:* I will give you a few examples with which most things in mines and collieries can be measured, or the contents obtained; such as pit-boxes, waggons, air-ways, currents of air, timber, coal, circular measurements, or other cubic contents. Here they are:—

"CROSS MULTIPLICATION."

The following will give you a knowledge how to find the area of any air-passage.

ft.	in.	
7	9	
3	6	
21	0	
2	3	
3	6	
	4	6
27	1	6

ft.	in.	
9	8	
7	6	
63	0	
4	8	
4	6	
	4	0
72	6	0

Another a little more difficult.

ft.	in.	p.		
240	10	8		
9	4	6		
2160	0			
7	6			
	6	0		
80	0			
	3	4		
		2	8	
10	0	0		
		5	0	
			4	0
2258	4	0	0	0

[illegible] the following area will yet [illegible] a distance more than

ft.	in.	
35	-	
13	-	-
257		
1164		
2830		
79	1	
4	9	-
24	-	
	4	
		1
10	1	
		1
50756	7	10

[illegible] a mail waggon, a box, or any [illegible] measurement.

The cubic contents of another.

ft.	in.	p.		
1	2	9		
1	2	9		
1	0			
	2	0		
		9	0	
	2	0		
		4	0	
		1	6	
		9	0	
		1	6	
			6	9
1	6	1	6	9
19	0	0	0	0
19	0			
9	6			
	1	7		
		9	6	
		1	2	3
28	8	5	8	3

ft.	in.			
16	9			
6	6			
96	0			
4	6			
8	0			
	4	6		
108	10	6		
8	4	6		
864	0			
6	8			
	4	0		
36	0			
	3	4		
		2	0	
4	6	0		
		5	0	
			3	0
911	9	11	3	0

Another, a little more difficult.

97	5			
18	3			
776	0			
970	0			
7	6			
24	3			
	1	3		
1777	10	3		
2	3			
3554	0			
1	8			
		6	0	
444	3			
	2	6		
			9	0
4000	2	0	9	0

The cubic contents of a Coal Box, length 2 *feet* 5½ *inches, by* 2 *feet* 7¼ *inches, depth* 2 *feet* 4¼ *inches.*

ft.	in.	p.				
2	5	6				
2	7	3				
4	0					
	10	0				
	1	0				
1	2					
	2	11				
	0	3	6			
	0	6	0			
	0	1	3			
		0	1	6		
6	4	9	10	6		
2	4	9				
12	0					
	8	0				
	1	6				
		1	8			
			1	0		
2	0					
	1	4				
		3	0			
			3	4		
				2	0	
	4	9				
		3	0			
			6	9		
				7	6	
					4	6
15	4	3	7	10	10	6

ft.	in.	p.
0	8	0
0	8	0
0	5	4
10	0	0
4	2	
	3	4
4	5	4

To find the area of a pit 13 feet diameter :

13	Diameter multplied by 13.
13	
39	
13	
169	
·7854	
676	
845	
1352	
1183	132 feet area, ·7326 being
132·7326	decimals, near 132¾ feet area.

To find circumference of a 13 feet pit :

3·1416
13
94248
31416
40·8408

Circumference 40¾ feet. See also pages 169 to 173 for more decimal measurements.

Examiners : The measurements are useful for colliery work ; you are able, we presume, to survey with a dial the workings of a mine ?—*Applicant :* Yes, and also to survey with the theodolite, and lay the workings on plan.

Examiners : Then you can land-survey, no doubt ?—*Applicant :* I am able to do land surveying ; but, you know, I am self-taught, not having spent any time in a surveyor's office.

Examiners : We require you to produce a plan of the workings of a mine surveyed and planned by yourself, and another on land surveying ; or else give some other proof that you are able to survey, &c.—*Applicant :* I have here a number of plans they

are not so well finished as they might have been had I served my time in a surveyor's office, but I know they are correct.

Examiners: Have you a perfect and thorough knowledge of mine gases?—*Applicant:* I think so.

Examiners: What do you know of mine gases?—*Applicant:* The atmosphere, I know, is a compound, or a mechanical mixture; in 100 parts, it consists of 21 of oxygen, and 79 parts of nitrogen, or 1 part oxygen and 4 parts nitrogen. Oxygen gas is a supporter of combustion, and if left to exert its native energies, it would melt the hardest substances, and set the earth in flames; everything would blaze with a rapidity which would carry destruction through the whole expanse of nature; oxygen would feed the flames on every side, and set at defiance the united efforts of every engine in the fire brigade. It is not so with nitrogen, the other ingredient of the atmosphere. If the air consisted of nitrogen only, every species of fire and flame would be extinguished, and all the tribes of animated nature instantly destroyed. Nitrogen, therefore, is not a supporter of combustion, but it is made in order to temper down or dilute the excessive strength of the oxygen.

Examiners: You have a knowledge, no doubt, of the composition of fire-damp?—*Applicant:* I think so. It is also a compound, and consists of two gases, hydrogen and carbon; in say five feet of fire damp, four parts are hydrogen, and one carbon. Hydrogen is combustible only in oxygen or air, but does not itself support combustion. Carbon is the chief constituent of coal, and is an ingredient in the composition of animals and plants.

Examiners: Do you know what after-damp consists of?—*Applicant:* Yes. It is composed of three gases or ingredients.

Examiners: What are they?—*Applicant:* In 11 parts of after-damp, 1 part consists of carbonic acid gas, 2 parts of watery vapour, and 8 parts of nitrogen. Carbonic acid gas, or black-damp, is a positive poison, nitrogen merely poisons by excluding oxygen, that is to say, carbonic acid lays violent hands upon its victim, and kills him at once, while nitrogen starves him to death by excluding all nourishment, therefore it is death to all who breathe it.

Examiners: From a few gases, then, nearly all other gases, when mixed, are obtained?—*Applicant:* Yes. Air, water, explosive gas, after-damp, and carbonic acid gas are obtained from only four gases.

Examiners: Name the four gases?—*Applicant:* They are the following—

	Symbol	Atomic Weight.
Hydrogen	H	1
Oxygen	O	16
Nitrogen	N	14
Carbon	C	12

Examiners: We presume you know the weight or specific gravity of mine gases?—*Applicant:* The specific gravity of the atmosphere is 1·000, fire damp 0·555, and carbonic acid or black damp is 1·524.

Examiners: Do the variations in the weight of such gases affect mines?—*Applicant:* Yes, mines are affected in the following manner: fire-damp being only 0·555, is little more than half the weight of the atmosphere 1·000, and as such is the case, fire-damp makes its way up into every hole in the roof, and into all workings which are very high, and to bring such gas down from those high places, both a propelling force in the current and a large quantity of it also is required.

Examiners: Does black-damp also affect mines by its great weight?—*Applicant:* Black-damp, or carbonic acid gas, being 1·524, is one-third heavier than the atmosphere 1·000, and near two-thirds heavier than fire-damp 0·555, and as such is the case it settles down to the floor, like mud in water, and fills the lowest workings, and to bring black damp up and away therefrom a strong propelling force in the ventilating current is required, and if the propelling force in the current is not sufficiently strong, the air will pass through the gas and not bring it away.

Examiners: How are mine gases discharged or produced?—*Applicant:* Just in the same manner as steam is discharged from a boiler when much compressed, when the weight on the valve is insufficient to keep it in. The strata in mines is pressed with gases to overflowing; and when gas discharges therefrom it is at the time when the atmospheric weight is insufficient to keep it in.

Examiners: How is it that a mine gives off a certain quantity of gas one day, and a much larger quantity on another?—*Applicant:* That is owing to the change in the atmospheric weight, which weight varies from one day to another. Just in like manner if the weight on a boiler valve be reduced just at the time when steam is blowing off, an increase in the quantity of steam will take place, and so an increase in the quantity of gas will take place, if the atmospheric weight be reduced when gas is discharging.

Examiners: But every mine does not give off alike the same quantity of gas, although the atmospheric weight be reduced from all mines alike, and at one and the same time. How is that?—*Applicant:* I know mines do not all discharge the same quantity of gas, and yet the atmospheric weight may be reduced

at the same time from each of them, that is owing to the variation in the compression of gas in the strata, caused by the fact that some mines have been discharging gas longer than others have; in like manner one boiler is less compressed with steam than others, because of its having been blowing off longer.

Examiners: But when mines are first opened out, they do not all give off alike the same quantity of gas, some may discharge a large quantity, others little or no gas. How is that?—*Applicant:* The strata from the bottom to the surface in some mines is more open than in others, and where the strata is open, gas escapes to the surface, and never can accumulate in the mine, therefore when the mine is opened out no gas or very little is found, while in others with no open strata a large quantity is found.

Examiners: Do you know how a motion of the current is caused to move along and through the workings of a mine?—*Applicant:* I think so. Its motion is caused by propulsion or exhaustion at one shaft or at the other, therefore, whether by propulsion or exhaustion, a great moving propelling power in the current is produced at the down-cast over that at the up-cast; the least minimum density and weight of the air is always at the up-cast, so that from the first yard at the up-cast, the air becomes more and more dense, and step by step, every yard in the air way along its route from stage to stage this propelling force increases, until the greatest maximum density and propelling moving weight is obtained at the down-cast, and this motion is the current produced. See pages 54 to 55 on ventilating powers or the current's motion.

Examiners: What mode of ventilation would you adopt in mines discharging explosive gas?—*Applicant:* The mode of

separate divisions. I would divide, split, or separate the air into distinct currents or parts of say 4,000 cubic feet of pure air per minute for each separate division.

Examiners: Why would you have divisions of air?—*Applicant:* Because by so doing I should prevent explosive gas from collecting into large quantities, as the danger lies in the collecting and exploding of too large a quantity of gas.

Examiners: Is it more safe, then, to have divisions?—*Applicant:* Yes, because, if 100 feet of gas were discharged per minute in the workings of one division, 500 feet of gas might be discharged in the workings of 5 divisions, and to ventilate all with one current, the whole volume of 500 feet of gas would be exploded at once, but only 1-5th of it if ventilated separately, and so the power of the explosion would be reduced to 1-5th, the quantity of choke-damp left after the explosion would be reduced to 1-5th, the danger to life would be reduced to 1-5th; and the quantity of air obtained by having divisions would be much increased, because the friction of the current would be much diminished.

(See pages 81, 126, 134, 135, 137, for plans.)

Examiners: You know then what is meant by friction in the air-current?—*Applicant:* It is a rubbing of the air-current along the roof, floor, and sides, in its passage through the mine.

Examiners: What steps would you take to reduce its friction?—*Applicant:* I would shorten its route by making divisions or enlarge the passage through which it had to pass (See page 106.)

Examiners: What plan would you adopt in the working out of coal?—*Applicant:* In every mine the one that would [illegible] the nature of the roof, floor, coal, &c.

Examiners: Could you adopt a plan suitable alike for all mines? *Applicant:* Impossible, except there were no change in the roof, floor, &c.; if it were so, then one plan of working out coal would do for every mine, but as it is not, I must first obtain a knowledge of the nature of the roof, &c., to enable me to adopt a plan suitable for the mine intended to work the coal out.

Examiners: We presume you know several ways then of working out coal?—*Applicant:* I have a knowledge of pillar working, bank or wide work, drifts, and long wall work, &c., &c.

(See page 121 on working coal plans.)

Examiners: Have you superintended the sinking of pits or shafts?—*Applicant:* I have done a little of that, having had to measure the sinking of shafts, and being present when putting in rings, water tables, and walling of shafts, &c.

Examiners: Have you had anything to do with engines, boilers, and furnaces, both above and below ground?—*Applicant:* I have some knowledge of such, but have not superintended the erection of the same.

Examiners: Can you calculate the nominal horse-power of a steam engine?—*Applicant:* I think so.

Examiners: We will suppose, then, the diameter of the cylinder to be 55 inches, travelling 200 feet per minute, and 7lbs. pressure on the piston, let us know its nominal horse-power?—*Applicant:* I will calculate its power in the following manner;

```
    55  Diameter multiplied by
    55
   ---
   275
  275
  ---
  3025
 ·7854
 -----
 12100
 15125
 24200
 21175
 ---------
 2375·8350  Square inches in the cylinder.
      220   Speed of the piston.
 ---------
 475167000
 47516700
 ---------
 522683·7000
         7  Average pressure on piston.
 ---------
Divided by 33000)3658785·9000(110 horse power.
                 33000
                 -----
                  3587
                  33000
                  -----
                  28785  Remainder.
```

Examiners: We will speed the engine to 360 feet per minute, and an average pressure on the piston of 20 lbs. per sq. inch above the pressure of the atmosphere, let us know its nominal horse power?—*Applicant:* I will do so.

```
 2375·8350  Square inches in cylinder.
      360   Speed of the piston.
 ---------
 1425501000
 71275050
 ---------
 8553006000
         20  Average pressure on piston.
 ---------
 17106012·0000  Carried forward.
```

Divided by 33000)17106012·0000(518 horse power
165000

60601
33000

276012
264000

12012 Remainder.

Examiners: Can you give the quantity of water a pump will lift, 12 inches diameter, 66 inches stroke, and 27 strokes per minute?—*Applicant:* I will try to give the quantity.

12 Diameter multiply by
12

144
·7854 Decimal area.
144 Circular inches multiplied by

31416
31416
7854

113·0976 Square inches of pump barrel.
66 Length of stroke.

6785856
6785856

7464·4416 Cubic inches.
27 Strokes per minute.

522510912
149288832

Divided by 277·274)201539·9232(726 gallons.
1940918

744812
554548

1902643
1663644

238·9992=238 inches and ·9992 decimals over.

WEIGHT OF WATER.

1 cubic foot 62·5 lbs.
1 cubic foot 6·25 gallons nearly.
1 gallon 10 lbs.
1·8 cubic feet 1 cwt.
35·84 cubic feet 1 ton.
11·2 gallons 1 cwt.
224 gallons 1 ton.
277·274 cubic inches 1 gallon.

Examiners: Do you understand hydrostatics or the pressure motion and force of fluids?—*Applicant:* I profess to know a little of that.

Examiners: Suppose a cask was filled with liquid, and a long tube inserted tightly into the top, the area of the cask being 2000 inches, and the area of the tube 1-10th of a square inch, what pressure would be produced by pouring 3 lbs. of water into the tube?—*Applicant:* I will try to give its pressure.

```
    10  Area of tube.
     3  Lbs. of water.
    --
    30  Lbs. pressure per sq. inch.
  2000  Area of cask.
  -----
 60000  Lbs. pressure.
1 cwt. = 112)60000(535 cwts. 80 lbs.
           560
           ---
           400
           336
           ---
           640
           560
           ---
            80
```

This will show 535 cwts. and 80 lbs. of pressure produced by 3 lbs. of water.

Examiners: Suppose two circular boards form a pair of bellows, a long tube half a square inch is inserted into the top, the area of the board is 144 square inches; pour into the tube 2 lbs. of water (after the bellows have been partly filled with water), what pressure will be produced?—*Applicant:* The pressure produced by the 2 lbs. of water will be 576 lbs.

144 Area of bellows.
4 Lbs. pressure per sq. inch.

576 Lbs. of pressure produced.

The weight and pressure of fluids lead to many strange and important results.

Examiners: You have some knowledge, no doubt, of pneumatics?—*Applicant:* I also understand a little of that science, such as the mechanical properties of the atmosphere, its resistence, its pressure, its elasticity; and how the air acts on barometers, syphons, syringes, air pumps, water pumps, fire engines, &c., &c.

Examiners: Have you a knowledge of mechanics?—*Applicant:* I have some knowledge of the mechanical laws of motion, such as the inclined-plane, the wedge, the screw, the pulley, the lever, and the balance; so that I know if power be gained there is loss in motion. (It would be well for Applicants to study much the above sciences.)

Examiners: Do you know the strength of materials, the breaking strain of chains, hemp ropes, steel and wire ropes, the strength of iron and timber?—*Applicant:* I have some tables and rules to show the same.

Examiners: Let us see them.—*Applicant:* Here they are:—

STRENGTH OF MATERIALS.

*To find the breaking strain of hemp ropes.**

$$\text{Breaking weights in tons} = \frac{\text{circumference squared in inches.}}{4}$$

Examiners: What is the breaking weight of a rope eight inches in circumference?—*Applicant:* You may find it in the following manner:

$$\frac{8 \times 8}{4} = 16 \text{ tons.}$$

To find the weight which may be safely appended to a hemp rope:—

$$W = \frac{\text{circumference squared in inches.}}{10}$$

Examiners: What weight might be safely appended to a hemp rope ten inches in circumference?—*Applicant:* Here you have it:

$$\frac{10^2}{10} = 10 \text{ tons.} \quad \text{Answer.}$$

COLUMNS.

Table of practical formulæ by which to determine the amount of weight a column of given dimensions will support, in pounds.

For a rectangular column of cast iron.....W= $\frac{15300\ 1\ b^3}{4\ b^2 + 18\ b^2}$

For a rectangular column of malleable iron.....W= $\frac{17800\ 1\ b^3}{4\ b^2 + 16\ l^2}$

For a rectangular column of oak.....W= $\frac{3960\ 1\ b^3}{4\ b^2 + 5\ l^2}$

For a solid cylinder of cast iron.....W= $\frac{9562\ d^4}{4\ d^2 + 18\ l^2}$

For a solid cylinder of malleable iron.....W= $\frac{11125\ d^4}{4\ d^2 + 16\ l^2}$

For a solid cylinder of oak.....W= $\frac{2470\ d^4}{4\ d^2 + 5\ l^2}$

Note—W = the weight the column will support in lbs.; b = the breadth in inches; l = the length in feet; d = the diameter in inches.

* Tables are to be had showing the breaking strain of ropes, &c. If the applicant be in possession of them, the examiners should be satisfied.

To find the ultimate transverse strength of timber.

1.—When the beam is supported at both ends, and loaded in the middle :—

Let L = length in inches.

B = breadth ,,

D = depth ,,

$$M = \begin{cases} 1672 \text{ for English oak.} \\ 1556 \text{ for beech.} \\ 1013 \text{ for elm.} \\ 1632 \text{ for pitch pine.} \\ 1341 \text{ for red pine.} \\ 900 \text{ for larch.} \end{cases}$$

$$W = \frac{D^2 \times B \times 4 \times M}{L}$$

$$\text{or } W = \frac{4D \times BD \times M}{L}$$

Examiners: What weight will it require to break a beam of pitch pine, supported at both ends, and loaded in the middle, the breadth being seven inches, depth nine inches, and length thirteen feet?—*Applicant:* You may find the same thus :

$$\frac{9^2 \times 7 \times 4 \times 1632}{156 \text{ ins.}} = 23727 \text{ lbs.}$$

The above result must be multiplied by three if the load is distributed uniformly along its entire length. It may easily be remembered, what may be learned from the above rule, that the strength of timber varies as the square of the depth multiplied by the breadth. Thus, a plank 11 × 3 laid flatways would bear little more than one-fourth of the weight that it would sustain edgeways, because 3 × 11=99, and $11^2 \times 3 = 363$. A plank of pitch pine of these dimensions, and 7ft. in length between the supports, would bear

Examiners: Let us have the strength of chains.—*Applicant:* I will.

Table of the weight and strength of chains.

Diameter.	Weight per Fathom.	Proof Strength	Diameter.	Weight per Fathom.	Proof Strength.
Inches.	Lbs.	Tons.	Inches.	Lbs.	Tons.
$\frac{5}{16}$	$5\frac{1}{2}$	1·27	$1\frac{1}{8}$	68	26
$\frac{3}{8}$	8	1·82	$1\frac{3}{16}$	76	29
$\frac{7}{16}$	$10\frac{1}{2}$	2·5	$1\frac{1}{4}$	84	32
$\frac{1}{2}$	$13\frac{3}{4}$	4·	$1\frac{5}{16}$	93	35
$\frac{9}{16}$	17	5·	$1\frac{3}{8}$	102	38
$\frac{5}{8}$	22	6·	$1\frac{7}{16}$	111	41
$\frac{11}{16}$	26	$7\frac{1}{4}$·	$1\frac{1}{2}$	120	44
$\frac{3}{4}$	30	10·	$1\frac{9}{16}$	128	48
$\frac{13}{16}$	36	11·$\frac{1}{2}$	$1\frac{5}{8}$	136	52
$\frac{7}{8}$	42	13·	$1\frac{11}{16}$	142	56
$\frac{15}{16}$	49	15·	$1\frac{3}{4}$	148	60
1	55	18·	$1\frac{13}{16}$	150	65
$1\frac{1}{16}$	60	22·	$1\frac{7}{8}$	162	70
			$1\frac{15}{16}$	171	75
			2	180	80

Examiners: We give you now a large number of questions, which have been asked now and again at several Boards of Examiners in the United Kingdom. If able to answer them your success is certain.—*Applicant:* I am glad to have the questions previously asked at the several Boards of Examiners, it will be my greatest endeavour to answer such to the best of my ability.

Mensuration.

1. Give a sketch of a triangle, and find the superficial area, the base 1236 links, and perpendicular height 78 links.

2. Give a sketch of a parallelogram, and find superficial area, 3725 yards by 2935 yards.

3. Give a sketch of a rhombus, and find the area, the length being 37·50 links, and 25·75 links wide.

4. Give a sketch of a polygon, and the formula to find the area of any given size.

5. Give a sketch of a circle, and a formula to find superficial area, when the diameter is 36 inches.

6. What are the cubical contents of a cylinder 36 inches in diameter, and 5 feet 6 inches in length?

7. What are the cubical contents of a cone, whose diameter at base is 36 feet, and perpendicular height 24 feet?

8. Give a sketch of a trapezium, and a formula to find the areas of the two triangles, the diagonal being 100 yards and perpendiculars 35 and 65 yards respectively.

9. How would you measure an air-way when the sides, roof, and floor are very irregular?

10. Is there more or less rubbing surface in a circular air-way than in any other shapes?

11. What is the sectional area of an air-way when the width is 7 feet 6 inches, and average height 5 feet 6 inches?

12. How many cubic feet of air passes per minute along an air-way 8 feet high by 10 feet wide, the velocity of the air-current being 450 feet per minute?

13. How much larger is an air-way 10 feet by 10 feet, than one 5 feet by 5 feet, and what is the rubbing surface in each?

14. How much larger is an air-way 6 feet by 6 feet, than one of 10 feet by 2 feet, and what is the rubbing surface in each?

15. If there were four air-ways 4 feet by 4 feet each, what would be the area and rubbing surface of all? Also the area and rubbing surface of one 8 feet by 8 feet? Say whether in

the former or in the latter would the largest quantity of air pass.

16. What is the difference in area between an air-way 4 feet 6 inches by 3 feet, and one 6 feet 6 inches by 5 feet, and give rubbing surface in each ?

17. Give the formula to find the circumference of a shaft, the diameter being 14 feet 6 inches.

18. Give the formula to find the area of a 15 feet diameter shaft.

19. Give formula to find area of the sides of a shaft, the diameter being 18 feet and depth 150 yards.

20. Give the formula to find cubical contents of a shaft, diameter 12 feet 6 inches, and the depth 220 yards.

21. Give the formula to find what quantity of bricks a shaft will take, 9 inches work, diameter 15 feet, and depth 156 yards.

22. How would you find the horse-power of a condensing engine, diameter of cylinder 20 inches, pressure on piston 7lb per square inch, and 150 feet per minute speed of piston ?

23. How would you find the horse-power of high pressure steam engine, with the cylinder 24 inches in diameter, and pressure on piston 16lb per square inch, speed of piston 200 feet per minute ?

24. What is the weight of water contained in a pipe one foot long by 10 inches diameter ?

25. What is the weight of water contained in a fathom of pipes, 15 inches in diameter, and the number of gallons ?

26. What is the pressure of water in pipes per square inch in pound, the diameter 12 inches, and height of pipes 250 feet ?

27. What is the weight in lbs., measure in gallons, and cubic inches of water, contained in a shaft 15 feet in diameter, and 1 foot deep ?

28. What is the weight in lbs., measure in gallons, and cubic inches of water contained in pipes 18 inches in diameter, and 100 feet in length?

29. What is the weight of 12 cubic inches of water?

30. What is the weight of one cubic foot of water in lbs. and measure in gallons?

31. How would you find the number of imperial gallons contained in a cistern 14 feet by 20 feet by 10 feet.

32. What is the weight in ounces of a cubic foot of water, at 60 degrees.

33. What are the cubical contents in inches in the imperial gallon?

34. How many bricks can there be made out of two cubic yards of strong clay?

35. How many bricks can be made out of $1\frac{3}{4}$ cubic yards of mild clay?

36. How many bricks of the ordinary size can there be made out of an acre of strong clay, 4,840 square yards and 1 foot deep?

37. Add together,

507	tons	18	cwt.	2	qrs.	12	lbs.
1670	,,	15	,,	1	,,	8	,,
47	,,	14	,,	3	,,	14	,,
490	,,	9	,,	2	,,	7	,,

38. How much would be required to pay 75 men a fortnight's wages, at the rate of 27s. $4\frac{1}{2}$d. per week?

39. What weight of material will have to be raised in a sinking shaft, 15feet by $5\frac{1}{2}$feet, and 40 fathoms deep, supposing it averages 130lbs. per cubic foot?

40. The sum of two numbers is 87,091, one of them 19,013, what is the other?

41. Find the square root of 94,206,480.

42. Extract the square root of 8,511,876, and 67,272,604.

43. The average wages of a colliery per man, were 5s. per day. A first advance of 10 per cent is given; a second is given of 12 per cent; a third of 15 per cent, all upon the gross earnings. What is the average of these advances? Reductions are made on the gross earnings; first of 15 per cent; second of 12½ per cent; third of 10 per cent. What would be the average wages after these reductions.

44. Subtract 278 chains 11 yards 2 feet 10 inches, from 500 chains 17 yards 1 foot 1 inch.

45. Divide 13 acres 2 roods 6 perches, by 19; and 3132·71 by 73·700.

46. What are the areas of air-ways 4 feet 8 inches, by 8 feet 9 inches; and 4 feet 5 inches, by 6 feet 2 inches; what is the total of the two?

47. Deduct 57 acres 1 rood 27 perches, from 91 acres 2 roods 17 perches, and find the value of the difference at £100 per acre.

48. What is the area of a shaft 9 feet 6 inches diameter?

49. What is the circumference of a circle whose radius is 8 feet?

50. Extract the square root of 289, and show the process.

Mines' Regulation Act, 1872.

51. When the underground workings are approaching old wastes of which no plans have been kept, what special dangers are the workmen exposed to? How would you guard against them?

52. State shortly the general rules as to the use of gunpowder or other explosive, in mines where inflammable gas has been noticed.

53. What is the requirement of the Act as to the number of shafts in use at each mine, and state shortly the exceptions to it that may be allowed.

54. In mines where there is inflammable gas, what special precautions are to be observed by the workmen, and by those in charge of the mine?

55. Give a short statement of the requirements of the act, regarding man-holes or places of refuge on underground roads.

56. What limitation does the Act impose on the employment of young persons between 12 and 16 years of age?

57. What are the duties of a Certificated Manager as described by the Coal Mines Regulation Act?

58. To what extent are single linked chains prohibited by the Mines Act?

59. Give a general abstract of the Mines Regulation Act, more especially those clauses relating to the safety of workmen and duties of Certificated Managers.

60. Under what circumstances would you withdraw the workmen?

61. State the chief provisions of the Mines Act of 1872 for the safety of mines and miners.

62. What are the regulations as to the employment of women, young persons, and children as regards their age and hours of employment?

63. State the provisions of the Act as to the ventilation of mines.

64. What are the regulations as to enginemen and firemen?

65. What precautions are to be adopted in approaching gas or water?

17

feet

5

51.

wastes

are the

them ?

52. S

or other

noticed.

78. What does the Act specify as to who may be employed about an engine, windlass, and gin?

79. Describe the material you would use in stemming the rt next the powder, what kind of tools you would stem with, d how you would light the shot?

80. What provisions does the Act provide for self-acting and ne planes, as regards persons travelling up and down, and in the horse roads?

1. What is the least thickness to be between two shafts used purpose of ingress and egress.

2. What size must the roads be which communicate with the afts or outlets of a colliery?

Boring, Sinking, Tubbing, Walling, Pumping.

Describe the process in sinking through marls, metals, rock, burr, and running sand.

What size or thickness of brickwork would you put into here marls, metals, linstey, and jointy rock is sunk nd would it be safe to omit bricking in any of the ls or rocks.

hat distance apart would you place walling rings in re marls, metals, linstey, and jointy rock have been ugh, should they vary in distance, and, if so, state the

ribe the method of putting in a length of brickwork oit, and what precautions should be taken where gas

aving placed a ring of brickwork in a shaft, and ow would you proceed with sinking in order to ing of brickwork below?

88. Should walling rings be laid level? and how would you lay them so?

90. How and where would you place water tables in a shaft, and would you prefer them made of iron, or wood lined with lead, and should they be level or dipping to a point?

91. What is the common source of danger to be guarded against in sinking?

92. What kind of foundation should rings be laid upon to be perfectly safe?

93. Which is the best way of slinging rings in broken ground, and making them safe until another length is put in below?

94. How would you sink a shaft perfectly perpendicular, and of the proper dimensions?

95. Suppose the metals, or other measures, for the support of rings or brickwork, are not good for a long distance, how would you proceed should 18 or 20 yards give way?

96. Which is the best process of tubbing off water and sand, and is iron or wood the most preferable?

97. How would you commence sinking operations in a place where you would have to sink through 30 feet of sand, about 30 feet deep from the surface.

98. If, while sinking a 16-foot shaft, you came upon a sand bed at 30 yards from the surface, and 21 feet in thickness, how would you proceed?

99. Suppose you were sinking a shaft through running sand with a wooden curve or iron castings, and you came upon a very large boulder or hard side, how would you proceed?

100. By what means would you keep tubbing perpendicular in going through sand.

101. Describe what sort of foundation you would rest tubbing upon for safety?

102. Give the size and strength of tubbing for shafts with the following diameters: 12, 13, 14, 15, 16, 17, and 18 feet.

103. How would you make secure a pumping lift in a shaft where it is bricked and tubbed.

104. How would you proceed with sinking, if you came upon a large influx of water?

105. How would you manage to blast the rock at the bottom of a shaft, when much water is always at the bottom?

106 Describe, by a sketch or otherwise, the different kinds of pumps used in a pit, and also the sliding pipe or suction, and describe its merits.

107. Sketch the form and give the size of shaft, for single and double cages, including ordinary provisions for pumping.

108. Describe the general arrangements, and size of pipes, and the mode by which 1,000 tons of water may be lifted from a 60-fathom pit in 24 hours. Also, give the contents, in cubic feet, of a place 10 yards long, 3 yards wide, and $2\frac{1}{2}$ yards high. If this place was full of water, how long would it take a pump to empty it, delivering at the rate of 20 gallons a minute, there being $6\frac{1}{4}$ gallons in a cubic foot?

109. Describe the class of engine necessary for the above work, with size of cylinder, stroke, and number of strokes per minute.

110. State the different methods of pumping water out of dip workings.

111. State the advantages of a series of lifts of pumps in a deep pit.

112. Suppose the water in a shaft should rise up above the bucket and clack doors, how would you proceed to change the bucket or clack piece ?

113. What should be the diameter of working barrel and length of stroke to lift 147 gallons of water at each stroke of the engine ?

114. What is the usual form in which a pit is sunk in this district ? give a reason for this, and state how the work is kept in this form ?

115. Explain fully the meaning of the following terms :— cradle, ground crab, springhook, and bunton.

116. Describe the best method of timbering, walling, and tubbing a shaft, giving the dimensions of the materials you would use for a 13 feet pit.

117. Describe fully the various kinds of cribs, and the method of laying them.

118. Describe the best method of sinking through a quick-sand; and what thickness of iron tubbing would be used in a shaft, where the head of water is 196 feet, and 14 feet diameter.

119. What is the effect of gas behind tubbing, and how would you guard against it ?

120. In sinking and opening out a colliery, what is the principle which should guide you in determining the position of the works ?

121. What is the proper thickness of brick lining for shafts 9 feet and 6 feet diameter ?

122. If you had to tub a 13 feet shaft, for a depth of 150 yards, how many, and what wedging cribs would you put in, and what strength of tubbing ?

123. Describe the process of laying a wedging crib, and putting in the tubbing.

124. How would you secure pumps in a sinking pit?

125. In what place have you had the management or superintendence of sinking operations, opening out a seam, and where situated?

126. If in sinking you meet with a strong blower of gas, what steps should be taken to make the shaft in a fit state of working?

127. Can you explain the ordinary method of boring?

128. Is there any particular scale of charges for boring, by the ordinary hand method?

129. Is steam power ever used in boring? Give the systems in use.

130. Can you describe the system of boring by the diamond rock drill?

131. What particulars can you give as to the cost of boring by the diamond rock drill?

132. Can you explain the process of putting tubbing into a shaft?

133. In plugging up the holes in the tubbing, what care is necessary?

134. What provision is sometimes made to allow the safe escape of the confined air?

135. How do you ascertain the amount of pressure which the tubbing has to resist?

136. How do you determine the proper thickness which the cast iron tubbing should be?

137. Can you explain the action of the lifting pump, which raises the water, from the mine to the surface?

138. Can you explain the action and working of a forcing pump?

139. How many horse-power would be required to raise 4,000 cubic feet of water per hour, from a mine 180 fathoms deep?

140. How many gallons of water would a steam engine of 50 horse-power raise from a depth of 200 fathoms in one hour?

141. What must the horse-power of an engine be, to pump 87 feet of water per minute, from the depth of 60 fathoms?

142. How many cubic feet of water will an engine of 50 horse-power raise per minute, from a depth of 90 fathoms?

143. What time will it take an engine of 40 horse-power to pump 4,000 cubic feet of water, from a depth of 60 fathoms?

144. Which part of an estate in a coal royalty would be the most advantageous to sink the up and down cast shafts, for the better winding of the coal, the better ventilation of, and the pumping of the water from, the mine?

145. Should the down-cast or the up-cast shaft be the largest, and why so?

Boilers, Engines, and Machinery.

146. Give a description of the high-pressure steam engine.

147. Give a description of the Cornish engine, and what sort of valves it has.

148. Give a description of the condensing engine.

149. When the water in a boiler has become dangerously low, what would you do?

150. Describe iron, steel, and wood conductors for winding shafts, and how they are arranged, and which you think the best for safety?

151. Which are the best kind of pulleys for round and flat hemp, steel, and iron ropes, and give the diameters best suited for different sizes of ropes?

152. Give the diameter, circumference, width, thickness, weight, strength of round and flat ropes, hempen, iron, and steel, to wind a weight of 2, 3, 4, and 5 tons.

153. Give a description of cages, their weight and strength, thus:—What would have to be the strength of a 1-box cage, box weighing 4¼ cwt., and to carry 8 cwt. of coal? Again, what would be the weight and strength of a 2-box cage, boxes weighing 4½ cwt. each, and to carry 8 cwt.

154. What would have to be the size, stroke, etc., of an engine for lifting 200 tons of coal each day of eight hours out of a 100-fathom pit.

155. What mode would you prefer in hauling coals out of dip workings?

156. Describe the best kind of boilers and appliances for the safe and economical production of steam.

157. In speaking of machinery, what is meant by horse-power?

158. Describe the fittings of a boiler, more especially those necessary for safety.

159. What is the effect of sediment, or incrustation forming in a boiler, and is any danger likely to arise from it?

160. What shafts and plant would be required to raise 100 tons per hour from a coalfield of 2,000 acres, 5 feet 6 inches thick, and an average depth of 300 yards?

161. Describe a high-pressure and a condensing engine, showing how to find the indicated and nominal horse-power?

162. What is Richard's Indicator, and how is it used?

163. Give details of the different parts of a high-pressure winding engine, whose cylinders are 80 inches in diameter, and 5 feet stroke.

164. How many and what sort of boilers would you have to drive them?

165. Give the proper size and strength of boiler plates for high pressure boilers.

166. What diameter of pumps will an 85 inch cylinder engine work from a depth of 121 fathoms, at a steam pressure of 15 lbs. to square inch?

167. What horse power must an engine be to raise 2000 cubic feet of water from a depth of 180 fathoms?

168. What number of boilers 40 feet long, 7 feet diameter, would be sufficient to work an 85-inch cylinder engine?

169. How many imperial gallons per minute of feed-water would be required to supply six boilers 288 nominal horse-power?

170. What kind of engines would you recommend to raise 1,500 cubic feet of water from a depth of 20 yards? Give power of engine, size of cylinder and lift.

171. What size of hauling engine would be required to draw 100 tons per hour up an incline 1,000 yards long, having a gradient of one in six?

172. If an engine with a four feet stroke having an initial pressure of 40 lbs. to the square inch, and the steam is cut off at a quarter stroke, what is the pressure at the end of stroke?

173. Give a description of the Lancashire and Cornish boilers, and their mountings.

174. Required the weight on a safety valve, at 20 inches from the fulcrum, with a pressure of steam of 45 lbs. per square inch.

175. Describe the Watt's indicator.

Modes of Coal working and opening out of Mines.

176. What mode of working out coal are you acquainted with?

177. What is meant by pillar and stall work, and give a sketch of each?

178. State the ordinary conditions for adopting the long-wall, stoop and room workings?

179. If a seam should have a dip or rise of 1 in 8, sketch what you consider would be a good form of long-wall working for it, having due regard to its ventilation and the direction of the main road?

180. Under the same conditions, give a sketch of stoop and room workings.

181. Show also a sketch of the long-wall working?

182. Under average conditions as regards roof and floor, what dimensions would you give the pillars, and what openings in the stoop and room workings of a 4-foot seam, 100 fathoms deep, with a view of combining safety, with the extraction of the greatest quantity per acre.

183. Explain the size of pillars most suitable for removal, and sketch the safest mode of removing them.

184. How large a bottom stoop, or pillar of coal would you leave in to support a 60 fathom pit, and on what principle is this determined?

185. Give a rough section showing the different seams in your district.

186. Give a sketch of other modes of coal working.

187. Why are there several ways of coal working adopted, and why will not one answer for all mines? Give your reasons.

188. What plan of coal getting can be pursued with the greatest economy and safety, as well as to get the greatest quantity daily?

189. What mode of coal getting is the safest as regards gas?

190. How and where would you take the drag of the air with the water guage?

191. How is a water guage affected when the air course is suddenly contracted or enlarged?

192. Where would you fix the registering thermometer in an up-cast shaft?

193. What method is adopted for working the steep seams of South Wales?

194. What is the system used in working the Dudley Thick or 10 yard coal?

195. How would you support the roof of a mine when working the systems known as board and pillar, also longwall?

196. Falls of stones are the cause of many accidents. How do you ascertain the danger of a stone?

197. If in driving a heading you meet with a fault throwing the coal down 20 yards, how would you work the coal on the other side?

198. What size of pillars would you leave for the support of the main road and shafts?

199. Have you had any experience in underground haulage. If so, what are the systems?

200. What gradients would you lay out for main roads so as to make the resistance equal for full and empty trams?

201. What is the least gradient at which a self-acting incline will work?

202. Which is the cheapest mode of conveying coal to the shafts?

Ventilation and Gases in Mines.

203. Give a description of furnace ventilation, or the best way to construct one, and where to place the same. Give, also, a description of a dumb drift.

204. How would you find the motive column, or difference between the weight of air in the down-cast and the up-cast shafts?

205. Describe shortly the different modes of artificial and natural ventilation.

206. Explain why artificial ventilation is more reliable than natural?

207. State whether exhaustion or propelling air gives the greatest and safest ventilation, and why? (Give the explanations separately.)

208. Where would you fix the mechanical ventilators to be the most serviceable?

209. Describe how a current is caused to move along the air-ways from the down-cast to the up-cast shaft.

210. What mode of ventilation can be relied upon as the safest? State the reason why.

211. Can you describe any other way to produce more air for the workings than that of dividing the currents? If so, state how you would produce it.

212. What quantity of air per minute does each person, horse, and pony require in a mine, where gases are given off from the strata?

218. What mode of ventilation requires the most air-crossings, and the least number of air-doors ?

214. Why should air courses have large areas ; and under ordinary conditions, as regards gas, what quantity of air should be circulating in a pit with 100 men and 50 horses in it, and what should be the least dimensions of an air-way for that quantity ?

215. How do you measure the quantity of air, and at what speed should air travel through workings ? Also, if the area of an air-passage be 52 feet square, what velocity must be attained in the air current to produce 85,000 cubic feet of air per minute ?

216. Explain the advantage of splitting the air.

217. If the velocity of a current going at the rate of five feet per second, had to be increased to ten feet per second, how much would the ventilating power have to be raised to produce the increased rate ?

218. Sketch what you consider a good furnace for a pit with 100 men, and give its dimensions and relative position to the shaft.

219. In driving a heading 200 fathoms long, how would you provide for ventilation ?

220. What mode of ventilation reduces the explosive mixture and reduces friction ? State the reason why it is so.

221. In what proportion does friction increase ? Show several ways how friction increases and diminishes. Also, what is the horse-power expended when the ventilating current measures 65,000 cubic feet per minute, and the water gauge is 0·60 inches ?

ooo By what means is density increased and diminished ?

223. How are mines affected when a change in the weather takes place?

224. Is explosive gas more sensitive to a change in the atmosphere than the mercury in the tube of a barometer?

225. When are mines in the greatest danger, and state how it is caused?

226. How are gases caused to expand out of the strata, and, at times, overflow the workings?

227. How does the temperature of the air increase while travelling through the workings, and what are the several causes?

228. By what route would you conduct pure air into the workings, and the impure from them?

229. Describe an air-crossing and its use?

230. How would you construct an air-crossing strong enough to withstand an explosion?

231. Describe a regulator and its use?

232. Will a change in the temperature of the air on the surface increase or diminish currents in mines, and, if so, how?

233. Will a change in the atmospheric pressure make a change in the quantity of air in the current?

234. How would you prevent outbursts of gas from the floor and roof?

235. How would you propel explosive gas from high points in the mine?

236. How would you propel carbonic acid gas from the lowest point in the mine?

237. How would you construct stopping so as not to be blown down?

238. What is atmospheric air composed of?

239. What is the composition of fire-damp, or carburetted hydrogen gas ?

240. What is the composition of black-damp, or carbonic acid gas ?

241 What is the composition of choke or after damp ?

242. What is the composition of carbonic oxide or white damp ?

243. What are nitrogen, oxygen, and hydrogen gases ?

244. What are the specific gravities of atmospheric air, oxygen, nitrogen, carbonic acid, carburetted hydrogen, hydrogen, and carbonic oxide gases ?

245. What are the atomic weights of all the above gases ?

246. What are the indications of the presence of all the above gases ?

247. What are the properties of the nitrogen gas, and will it support combustion or respiration ?

248. What are the properties of oxygen gas ; will it support combustion, and is it essential to the support of animal life ?

249. What are the properties of carbon, does it support combustion, and is it essential to support animal life ?

250. What are the properties of carboncic acid gas, and how does it act upon animal life ?

251. Is after damp called by any other name, and how does it act upon animal life ?

252. How does carburetted hydrogen gas act upon the animal system ?

253. Where is after-damp found after an explosion ?

254. Immediately after an explosion in a mine, which of the two shafts would you prefer to descend, the up-cast or down-cast shaft ?

255. How does an explosion expend itself—against the current of air or with it?

256. Which is the greatest explosive mixture? and in what proportions of air and gas will an explosion take place?

257. What is the mixture of explosive gas and atmospheric air when it is so reduced as only to show a blue light on the flame?

258. In what proportions will gas and air have to be mixed in order to extinguish the flame of a lamp?

259. In a mixture of air and gas where safety lamps are used, what should be done to prevent an explosion should the lamp become filled with flame?

260. Will the flame pass through the gauze if suddenly jerked, when in an explosive atmosphere?

261. Why will the flame not pass through the gauze if carried carefully and protected with a shield?

262. How many parallel wires are there to an inch in the gauze of a safety lamp?

263. How many apertures are there in a square inch of safety-lamp guaze?

264. What is the thickness of wire from which a safety-lamp guaze is made?

265. How is it that different parts of a mine vary in the quality and quantity of its gases?

266. How would you act should the gas continue to burn in the safety-lamp, after drawing down the wick?

267. Describe the Stephenson, Davy, and Clanny safety lamps; which do you think the best and safest, and why? and what constitutes their safety?

268. What is gunpowder made of?

269. What is the composition of gunpowder smoke?

270. How would you make a cartridge ?

271. Sketch what you would call a good furnace for 80,000 cubic feet of air per minute.

272. In travelling the air-ways of a mine, how would you instruct your firemen to proceed ?

273. How would you lay out your works, so as to ensure the least damage in case of an explosion ?

274. How would you proceed to remove a sudden accumulation of fire-damp ?

275. State the rule for finding the weight of a column of air ?

276. What method would you adopt for obtaining a large amount of air with but a small water gauge ?

277. How would you distribute the air in a mine, working 100 tons per day ?

Surveying and Planning on the surface.

278. By what means would you ascertain the proper dip of a mine ?

279. How would you keep headings, levels, and tunnels properly and correctly ?

280. For survey above and below ground a chain is used. What sort and length of chain is best adapted, the length of the links, and the number of links per chain ?

281. What is the vertical rise of an inclined plane whose angle is 36 degrees, and slant distance 400 links ?

282. Suppose a vein of coal, at an angle of 32 degrees with the horizon, to what depth would a shaft have to be taken to catch the vein, if it is set at a distance of 80 yards from the outcrop ?

283. Suppose a vein of coal at an angle of 56 degrees with the horizon, and the shaft has to be taken to a depth of 141 yards to catch the vein, at what distance is the shaft placed from the outcrop?

284. If in a shaft a seam of coal is cut through at a distance of 40 yards from the bottom, and a tunnel has to be driven at the bottom of the shaft in the direction of the seam, what distance will the tunnel have to be driven, supposing the seam to dip at an angle of 20 degrees?

285. If, in driving the west levels in a seam of coal dipping to the south one in six, an up-throw fault of 15 yards is met with, what would you do to recover the coal? and, if it were tunnelled out, what would be the length of the tunnel? Also, what length of tunnelling, if dipping two in seven, with an up-throw fault of 37 yards?

286. Does the magnetic needle keep true north, and, if not, what are its variations yearly?

287. Have you, or any one, discovered why the needle oscillates, and by what means is it found?

288. How are working plans kept correctly when this oscillation is constantly going on?

289. Describe the compass, and explain the circumstances under which it is unreliable.

290. Explain what is meant by the scale of $\frac{1}{2}$ inch to the chain.

291. Describe how you would plot a survey on paper, and name the instruments you would require to use?

292. Why is it necessary to make deductions from the measurements of mines which rise or dip, and how would you find the correct measurements?

293. Sketch on paper as near as you can the following bearings of a survey:—

N.E. 82°, and 68 links.	N.W. 35°, and 87 links.
S.E. 51°, ,, 95 ,,	N.W. 87°, ,, 140 ,,
N.E. 63°, ,, 78 ,,	S.W. 52°, ,, 140 ,,
N.E. 20°, ,, 97 ,,	S.E. 48°, ,, 85 ,,

294. Produce a complete plan of pit workings showing the ventilation, also a plan of survey and survey book.

295. What is understood by the term "true north" and "magnetic north?" Is there any difference? If so, say what.

296. Find the weight of coal in an acre of a seam 5 feet 6½ inches thick, taking the specific gravity at 1·25.

297. Describe the difference between the fast and loose needle dialling.

298. What dial would you prefer for surveying steep measures, and why?

299. What is the use of the vernier?

300. In a heading going S. 71° E, what must be the course of a cross-heading going at right angles to the north side?

Examiners: We are glad you are so well informed on the subject of mining; we hope a certificate as mine manager being granted, you will always be found worthy of such, by constant care and attention.—*Applicant:* It will always be my greatest delight and pleasure to give satisfaction, to save life and property.

P.S.—All practical men should bestir themselves, and obtain the information required for the management of mines. They have got the practical knowledge, all they require is a theoretical knowledge. If mines are to be managed properly for safety and economy, men must be obtained with a knowledge both of the practice and theory of mining. A class of managers so qualified would be unequalled; and any person able to answer the preceding questions, and properly understanding them, will not, I venture to say, be far from the mark, and should satisfy both examiners and employers, as well as the public.—W. HOPTON.

A LECTURE

ON

THE ATMOSPHERE;

ITS

CHANGES AND EXPLOSIVE GASES:

BY WILLIAM HOPTON,

"CERTIFICATED" MINE MANAGER.

The atmospheric air is the foundation of my discourse. When God breathed into man the breath of life, he gave him good, pure air to breathe. It was not given grudgingly, nor sparingly, but given plentifully, and in abundance.

It was given to sustain, to nourish, and to support him; and the more we know of its properties, the more we shall estimate its value and its worth; because it is useful for many things, if not useful for all things. The air we breathe maintains the clouds in the heavens, and gives buoyancy to the feathered tribes as they fly along through it. It raises balloons, smoke, vapour, and all noxious gases to the heavens.

It also throws back light, or gives a reflective power, by which objects are enlightened. It is owing to the atmosphere that the

heavens appear bright in the day-time; for, without it, only that part of the heavens would be light or luminous in which the sun is placed? and if we could live without air, and should turn our backs to the sun, the heavens would appear as dark as in the night time. This reflective power of the atmosphere is the means by which objects are enlightened so uniformly on all sides. The want of this reflective power would cause a strange alteration in the appearance of things, the shadows of which would be so very dark, and their sides, enlightened by the sun, so very bright, that, no doubt, we could see no more of them than their bright parts; and for a view of the other parts, we must turn them half round, or wait until the sun came round upon them.

But what would be the result, had we a world void, or destitute of air? In a world void, or destitute of air, the feathered tribes would have no use for their wings, for they could not fly; nor could a fish swim in the ocean—it would sink to the bottom. A cat, a mouse, or a bird in a room void of air, would expire in a few moments. To have a world void or destitute of air, music would lose its charms; neither could the sound of bells and voices be heard; however loud we might call from the top of the voice, we could not be heard. To have a world void of air, the medium through which sound is conducted would be lost; and, if so, we should be no better than people who are deaf and dumb. Everything would have to be conducted by signs and motion; but, I am glad we have not a world void or destitute of air.

Having shown a few useful properties of the air, I will now endeavour to show of what it consists.

The atmosphere is a compound, or a mechanical mixture; a compound is a mixture of ingredients, that is, several things

mixed or blended together to make one, therefore, the atmosphere is a compound of two ingredients composed of two opposite principles. One ingredient is the source of flame and life; the other ingredient is destitute of both, yet producing, by their different combinations of mixtures, the most diversified, beneficent and good effects. These two ingredients of the atmosphere are termed oxygen and nitrogen gases. To give an explanation of the two gases, it will be well to show first the properties of oxygen, and then the properties of nitrogen.

Oxygen is not a combustible, but a supporter of combustion. That is to say, it is not like the gas found in coal mines, which explodes at a naked light; neither is it like the gas in the street, so that, if it filled a room, it might be exploded; not so, I say, with oxygen gas, it cannot be exploded, it only supports and feeds the flame.

If the air consisted of oxygen only, we could not make the poker very hot, but it would burn; nor could we extinguish a candle but by cutting off the wick; and if a house should be on fire, the consequences must be awful indeed, as there would be no means of extinguishing the devouring element. If oxygen gas was left to exert its native energies, it would melt the hardest substances, and would set the earth in flames. Not only would such articles as wood and coal burn, but even stone, iron, and other substances, would blaze with a rapidity which would carry destruction through the whole expanse of nature. This terrific oxygen would feed the flames on every side, and set at defiance the united efforts of every engine in the fire brigade; and water, in such an atmosphere, would have no power in extinguishing the flames, but only support the conflagration, as water in 100 parts is composed of 85 parts

oxygen, and 15 parts hydrogen. Indeed, if the air consisted of oxygen only, the whole world must shortly be in one general conflagration; and it has been imagined that the earth may be consumed in this very manner at the last day, were the Author of nature to take away nitrogen from the air, and leave oxygen alone remaining. Nor could we breathe oxygen by itself; it would cause our blood to circulate with greater rapidity, and soon waste and destroy the human frame; therefore, we have some knowledge of what the result would be if our atmosphere consisted of oxygen only.

The other ingredient of the atmosphere is nitrogen, of which I have very little to say, only this, if the air consisted of nitrogen only, every species of fire and flame would be extinguished, and all the tribes of animated nature instantly destroyed. Nitrogen then neither supports combustion nor enables animals to live; but, as a component part of the atmosphere, it is made in order to temper down or dilute the excessive strength of the oxygen.

The Mixture of Oxygen and Nitrogen Gases.

The two gases of the atmosphere will not do in a separate state, unless mixed in such proportions as they now are by Providence, they supply the means of carrying out the great system of nature. The mixture is constituted as follows:—In 100 cubic feet there are 21 parts of oxygen and 79 parts of nitrogen. The mixture of these gases is everywhere and always alike, yes, on the mountain top and in the plain, in England, in America, in Africa or New Zealand—ever the same, 21 parts oxygen and 79 of nitrogen. It will not do, therefore, to have

more or less of either of these gases. I know the atmosphere is daily deprived of its oxygen, by fires, combustion, and flame, and consumed also in the lungs by every person and animal that breathes the air; yet the Divine mind has not overlooked this great consumption of oxygen without providing an equivalent supply, which is obtained from the leaves of trees and other vegetables, which give off the quantity of oxygen required, and no more, so that the mixture is nicely balanced and proportioned, continuing always and everywhere the same.

What an all-comprehensive, intelligent mind it shows! To cause one simple principle in different combinations of mixtures to produce so many important beneficial effects! What dreadful havoc would be produced in the whole system if such substances as oxygen were not nicely balanced and proportioned! These facts demonstrate the infinite knowledge and wisdom of the great Contriver of the universe, in the nice adjustment of every circumstance so as to preserve the balance of nature, and to secure the happiness of his offspring.

Let us see what the effects would be if the mixture were to be altered.

To alter the mixture (by weight) from 21 to 37 parts of oxygen, and the nitrogen from 79 to 68 parts, gives what is called laughing gas, which, when inhaled into the lungs, will produce fits of laughing, leaping, running, and many other delightful emotions. Then, again, if the mixture were altered to 56 parts oxygen and 44 parts nitrogen, it would produce instant suffocation to all who attempted to breathe it.

These gases, producing such effects, compose the air we breathe, the only difference being in the mixing of them – adding and diminishing the quantities.

Having thus demonstrated the mixture, I will now speak of the weight or specific gravity of such gases, which is of equal importance.

The weight of oxygen is 1·1007, that is, near 33 grains to 100 cubic inches of the atmosphere. The weight of nitrogen is 0·9748, or near 30 grains to 100 cubic inches of the atmosphere. That is to say, the relative weight of the two gases is what a 33lbs. weight is to a 37lbs. weight, the nitrogen being a small degree lighter than the oxygen; and it is wisely contrived so to be, for were it otherwise, that is, were oxygen a small degree lighter than nitrogen, so that the latter would be a degree heavier than common air, it would occupy the lower regions of the atmosphere, and produce universal sickness and death; because, instead of ascending as it now does when thrown off by the lungs in breathing, it would descend to the surface of the earth, to be breathed over and over again.

Here we again perceive an admirable adaptation of means to an end, and from ignorance of such facts the bulk of mankind do not understand the blessings they enjoy.

Having given, then, a brief explanation of the atmospheric air as a compound, together with its mixture and weight, I will now speak of its expansive and constracting properties.

You know, by exerting sufficient force, a piece of india-rubber may be pulled or stretched out to three or four times its natural length, and, immediately that force is removed, it returns to its original dimensions. I know we cannot take hold of and grasp the atmosphere as we can india-rubber, and pull it out, yet we can do that which amounts pretty nearly to the same thing. Mr. Boyle tells us that he expanded the air, with an air-pump, until it swelled out and occupied a space 14,000 times larger than it

usually occupied; that is to say, the air expanded out, until one cubic foot would fill a room thirty feet in length, thirty feet in width, and fifteen feet in height.

Again, another person informs us that he compressed or contracted the air, until it occupied a space 40,000 times less than it naturally occupied; that is to say, the air, in this case, was compressed until one cubic foot, or the same amount of the air which filled a room thirty feet long and thirty feet wide, by fifteen feet high, was pressed into a space only 1-24th part of an inch.

It is also said, that were it possible to transport a person from the earth, with the same pressure of air in his body as when on the surface, to a place five hundred miles high, one breath of air from his lungs would swell and expand out, until it would fill a sphere as large as this globe.

By what I have now stated, every person will see that the expansive and contractive properties of the air are very great. I must now leave the subject of expansion, having to speak of it again shortly. I will now speak of the height and weight of the atmosphere.

As we ascend into the higher regions of the atmosphere, we find our bodies pressed upon with less and less weight than on the surface of the earth; if, therefore, we were to ascend a mountain, or go up in a balloon, our bodies would be pressed upon with less and less weight than on the earth's surface, and with more and more weight as we descend.

In proof of this, a number of gentlemen once ascended in a balloon to a very great height; in doing so, their hands and feet were much swollen, so that the skin of their hands and feet had to be cut. Again, a number of gentlemen, in a journey among

the mountains of Peru, were surprised to find that they had great pangs of straining and vomiting, and also casting up of blood: and, no doubt, had they remained two or three hours longer, they would have died. That shows, if we ascend to a very great height, the pressure of the atmosphere on our bodies is so reduced, that it is not sufficient to counter-balance the pressure of the fluids in the body.

The atmosphere, then, is considered to be forty-five miles high: this height is known, as before stated, by the weight of it diminishing and increasing as we ascend and descend; therefore, the atmosphere must press upon itself, so that the nearest yard of air to the surface of the earth is pressed upon by the whole weight of air above.

I will illustrate this subject a little; therefore let us imagine that, instead of a layer of the atmosphere forty-five miles high, we have a number of wool packs the same height. If such be the case, will not the nearest pack to the ground be pressed upon by the weight of all above, and also pressed into a much smaller space than the uppermost one? Just in like manner, then, the lower part of the atmosphere is pressed upon by the whole weight of that above.

It is evident then we live at the bottom of a very deep sea, a sea forty-five miles deep, not of water, but a deep sea of air, and at the bottom of this deep sea, there is a great weight always pressing upon bodies and substances which lie on its floor, or on the earth's surface. Now, the average weight of air pressing on the earth's surface is fifteen pounds per square inch, or 2,160 pounds upon every square foot; and as the area of the whole earth's surface is near two hundred thousand millions of square miles, the total weight of air pressing on this globe is twelve

trillions, forty-three thousand four hundred and sixty-eight billions, and eight hundred thousand millions of pounds; or five thousand billions of tons.

Five thousand billions are very soon said, yet the quantity too great for any person to conceive. It would find employment for all the people in England, men, women, and children, to count the number in twelve months, and work hard twelve hours each day. Such is the weight of air pressing on the earth's surface.

Living, then, as we are, at the bottom of this deep sea of air it is evident the pressure on our bodies is very great; it is estimated at near fourteen tons; yet a small quantity of air within the human body, which will not weigh above a single ounce, will, by its strong elastic force, counteract the effect of this tremendous pressure, and prevent us being crushed to pieces. A room is full of air, and were it not for the strong elastic force of it within, counterbalancing the weight of that without, we should all be crushed to death by the falling of the building; and every glass window would be shattered to atoms. It is this great weight of the atmosphere which raises water in our forcing pumps, and supports quicksilver in barometers, and also prevents the water in our seas and rivers from boiling, and evaporating into steam. Take the pressure away, and all liquids would at once boil; therefore, the pressure keeps the steam down, and prevents boiling.

Liquids may be made to boil by two methods; we may either take away the pressure, and allow the natural heat of the liquids to act, or add so much additional heat to overcome the pressure. This weight of the atmosphere is the earth's great boiler valve, preventing the outbursts of gases pressed and pent up in the earth's strata. Let the Author of the universe remove away

this pressure, and the whole globe would shortly be in flames. The whole earth's strata, like steam in a boiler, is pressed with gases to overflowing, and only prevented from a tremendous outburst by the atmosphere being equal in weight to the pressure of the gases therein; then remove it, I say, and the earth would shortly be in flames. I know many people will say it is all a delusion, because the pressure of the atmosphere on their bodies is not felt; yet what I have stated is certainly the case.

How this pressure acts on pumps.

A respectable gentleman in Scotland applied to a friend, in order to obtain his advice respecting a pump, which he had constructed at a considerable expense. He told him that, notwithstanding every exertion, he could not obtain a drop of water, although he was sure there was plenty in the well, and although he had plastered the well top all around, and blocked up every crevice. When the well was inspected, it was found to be air-tight, so that the atmospheric pressure could not act on the surface of the water; but an orifice was at once made in the well, and water flowed from the spout abundantly. Again, one of the Grand Dukes of Tuscany wished to pump water from a very deep well, but having erected his pump, it was found that the water would not rise in the pump-barrel. This very much surprised his highness, and he called together the philosophers, in order that the mystery might be solved. Now, the opinion hitherto of the rise of water in a pump-barrel was, that nature abhorred a vacuum, but why it did not rise for the Grand Duke was a mystery. The pump-makers were then questioned, and they affirmed that water never would rise more than thirty-four

feet, but why it was so they could not tell. Matters remained in this state until one of the pupils of Galileo undertook the investigation, and he made this important discovery,—that just as water could not be pumped more than thirty-four feet, neither could quicksilver be pumped more than thirty inches, because the weight of the atmosphere, pressing on the surface of the water, balances that in the pump-barrel, therefore, by every stroke of the pump it takes away its load, but it is the atmospheric weight which supplies it with another load of water as often as it removes one.

How this pressure acts on barometers.

Just on the same principle, then, mercury is also balanced in the tube of a barometer by the atmospheric weight. I say balanced, because it is just on the same principle as two weights in a pair of scales, the mercury being in one scale, and the atmospheric weight in the other, so that thirty inches of mercury, and thirty-four feet of water, balance a weight of air forty-five miles high.

You have seen that the mercury in the tube of a barometer moves up and down; now the cause of this is changes that from time to time take place in the atmospheric pressure, so that when the mercury moves upwards the atmospheric pressure is increased, but diminished when it falls down. This change in the atmospheric weight is just on the same principle as tides of water in the ocean. Tides of water roll along from one part of the ocean to another, by which its weight varies in proportion to its depth. So, I say, we have tides of air rolling along from one part of the globe to another, and as this atmospheric tide rolls along, its

weight varies accordingly. These tides in the atmosphere are caused by the rise and fall of the temperature in separate parts of the globe. The air expands and swells out in one part of the globe in consequence of a rise in the temperature; in another part it contracts into less space by a fall of temperature. And it is owing to this atmospheric contraction and expansion that currents of air, or wind, move from one part of the globe to another. Now, these winds on the surface show the great wisdom of God. Had it been otherwise, smoke, vapour, noxious gases, chemical stenches, and other smells, would remain in the places whence they were emitted, producing universal sickness and death.

How this change in the atmospheric weight affects mines.

Now, this variation in the weight of the atmosphere affects greatly the gases discharged in mines, on the same principle as steam discharged from a boiler. If when steam is blowing off from a boiler, you at the same time take a little weight off the valve, will not an extra quantity be dicharged? Atmospheric weight, then, is the earth's great boiler valve, preventing the outburst of gases pent up within the earth's strata. Now, when this weight, which is, say, 15 lbs. to-day, is reduced to 14lbs. to-morrow, an extra discharge of gases takes place in mines.

If what I have just stated be correct, there is another question to solve, that is: If this atmospheric pressure be simultaneously reduced in all mines, and the discharge of gas takes place from all, how is it that each mine does not discharge an equal quantity of gas? I will explain this by a simple illustration. Suppose we had three boilers full of steam, the weight on each valve

being 15lbs. The steam in one boiler is so compressed that a great quantity of steam is discharged; the next, not so compressed, blows off less steam, and the third, being but slightly compressed, discharges very little steam. Now, if 1lb. weight be taken from each valve, the greatest discharge of steam will be from the boiler most compressed. And so, when the atmospheric pressure is reduced from all, the greatest quantity of gas will be discharged from those mines that are most compressed.

Again, if the atmospheric pressure is the same in all mines, how is it that the compression of gases is not alike in all? I answer, because explosive gas has been discharged from one mine for a longer period than from another, diminishing the compression in proportion; just in the same manner as steam being less compressed in the boiler which has been longest blowing off. From what I have stated it will be understood that one mine discharges more gas than another in proportion to the time which such discharges occupy, or the strata to surface more open.

Mines vary not only in the quantity, but also in the quality of their gases. One discharges pure explosive gas, another a mixture of the two gases called explosive gas and black-damp, while a third discharges black-damp alone. It may be asked why mines vary in the quality of gases discharged; which may be explained in the following manner:—Suppose we had a mine newly opened out, in which the explosive gas in the strata is so strong as to overpower, for a time, the atmospheric weight, it will discharge a large quantity of gas until its compression is reduced nearer and nearer to the weight of the atmosphere, after which the discharge of explosive gas will be only occasional, according to the changes in the atmospheric weight, which

weight varies accordingly. These tides in the atmosphere are caused by the rise and fall of the temperature in separate parts of the globe. The air expands and swells out in one part of the globe in consequence of a rise in the temperature; in another part it contracts into less space by a fall of temperature. And it is owing to this atmospheric contraction and expansion that currents of air, or wind, move from one part of the globe to another. Now, these winds on the surface show the great wisdom of God. Had it been otherwise, smoke, vapour, noxious gases, chemical stenches, and other smells, would remain in the places whence they were emitted, producing universal sickness and death.

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to-day is 15lbs., and to-morrow may be reduced to 14 lbs., a proportionate discharge then taking place. Consequently, when the atmosphere returns to its former weight of 15lbs., the air itself is then forced into the strata to fill up the space vacated by the gas when the atmospheric weight was lowest; the air then works in and out of the strata, backwards and forwards, and mixes with the gas therein, as the same reduced pressure which caused the gas to expand and rush out will also force the air in. The weight of air never being long at a standstill, it works backwards and forwards, into and against the strata, like a person drawing in and letting out his breath. By this forcing of atmospheric air into the strata, a mixture of explosive gas and black damp is discharged, which is given off at intervals until all the explosive gas is exhausted, after which the mine discharges black-damp only. In the same manner a person lets air into his body by breathing, and that air is converted into nitrogen or carbon before it is discharged. By what I have just stated, you will understand why one mine discharges pure explosive gas, another a mixture of the two gases, and a third black damp only.

Again, gases do not vary in quality and quantity only, but also in weight, and this variation in weight very much affects mines. I will now show the weight of those gases, and how they affect mines. The weight, or specific gravity of the atmosphere, is 1·000; therefore, one foot of it will weigh nearly two feet of explosive gas, because the specific gravity of explosive gas is 0·555. Explosive gas, then, being so much lighter than air, is the cause of its so affecting mines, because it makes its way up into every hole in the roof, and all very high workings; and like corkwood in water, or a balloon in the air, it rises to the

top of all such workings, and overflows them, and to bring the gas away a propelling force in the air current is required, as well as quantity.

Again, one foot of black damp will weigh nearly three feet of explosive gas, because the specific gravity of black damp is 1·524, and as such is the case, it settles downwards to the floor, like mud in water, and fills the lowest working places, and to bring it also up therefrom, a propelling force in the air current is required as well as quantity; if not, the gas will not mix with the air, but pass through and leave it there.

Let every fireman, deputy, underlooker, and manager, remember then such laws of nature, and never depart from them. For the fixing of brattice cloth to propel downwards explosive gas from any high working place, the cloth must be so arranged that the largest space for the current to pass to the working place must be in going to the gas, and the least space in coming from it, so that force may be obtained in the return current; if not, the air will pass through the gas, and not bring it away. Then again, for the bringing up of black damp from below out of deep workings, the space behind the brattice cloth must be least in coming from the working place, and largest in going to it, so that force in the return current, as well as quantity, may be obtained. When this is not attended to, miners often work in jeopardy when it might at once be removed.

I will now speak of the composition and mixture of those mine gases. Fire-damp is a composition of two gases, termed hydrogen and carbon; the two being mixed together form the carburetted hydrogen gas called fire-damp. In five feet of this gas four parts of it consists of hydrogen gas, and one part of carbon.

Again, when an explosion of this gas takes place, another gas is produced, which is called after-damp, or choke-damp; this after-damp is also a composition of three gases—viz., nitrogen, carbonic acid, and watery vapour. In eleven parts of after-damp, one part consists of carbonic acid, two parts of watery vapor, and eight parts of nitrogen.

What can fire-damp also be obtained from? I answer, from water and wood, because hydrogen is one of the ingredients of water, and carbon is also one of the ingredients of charcoal; therefore, the two ingredients of fire-damp can be obtained from water and wood.

Also, what can after-damp be obtained from? I answer, from air, water, gingerbeer, and wood, because nitrogen is one of the ingredients of the air, and carbonic acid is one of the ingredients of gingerbeer and of charcoal. Watery vapour, the other ingredient, is water when condensed; so that after-damp can be obtained from air, water, gingerbeer, and wood.

What effect does after-damp produce on a person when breathed? The following: Carbonic acid gas is a positive poison; nitrogen merely poisons by excluding oxygen: that is, carbonic acid lays violent hands upon its victim, and at once kills him, while nitrogen starves him to death by excluding all nourishment; therefore, it is death to all who breathe after-damp. When breathed it takes away a person's strength, his limbs fail him—they become heavy and powerless, he then feels a deathlike sickness, yet without pain, and at last he passes away insensibly, like a person going to sleep, and in that state he enters eternity. I have a knowledge of the effect it produces, having been for a long time insensible through breathing it.

Again, as to the explosive mixture of fire-damp. I have before stated that fire and flame are supported by the oxygen in the air. If flame could exist without oxygen, the blaze at the end of a gaspipe would pass through it, and along to the whole magazine of gas, and instantly explode it; but no! it is impossible, oxygen in the air is required to feed it. A proper mixture, therefore, of explosive gas with oxygen is required to cause an explosion. I say a proper mixture, because the power of an explosion is in proportion to the mixture as well as the quantity of such gases. The greatest explosive power is obtained when one foot of fire-damp is mixed with say seven or ten feet of air, but an explosion will take place when one foot of fire-damp is mixed with from four to twelve feet of air; therefore, it requires a larger quantity of air than gas to cause an explosion, and a larger quantity of air than gas to prevent one. So that gas, you see, is rendered harmless by adding more pure air into the same quantity of gas, that is, it becomes further from the explosive mixture. Gas is not destroyed, it is only rendered harmless, by a large admixture of atmospheric air: the old goaf, and other places charged with gas to overflowing, cannot be ignited if the atmosphere is not allowed to mix with it. This I have several times proved to be correct.

Many know not why the Stephenson safety-lamp becomes extinguished in a mixture of fire-damp. It is because the lamp is so constructed with air-passages as to admit only just the quantity of air required to feed the flame, and an explosion taking place within the lamp enlarges the flame, and an enlarged flame requiring more air, which the passages do not supply, it dies out just as a person would die for the want of food.

My next subject is ventilation. What are we to understand by it? or how does a current of air descend one shaft and pass up another? This may be better understood by a very simple illustration of two weights in a pair of scales. Suppose, then, we had a pair of scales with a 15 lb. weigh in each scale, in that case, the weight at each end being equal, the scales would be perfectly balanced; but if we add one pound to one, making it 16lbs., that weight would overbalance the other; and the same effect would be produced by taking off a pound from one end, reducing it to 14 lbs. What I wish you to understand by this simple illustration is this: Remembering that the 15lbs. of atmospheric weight press alike on the top of one shaft as on the top of another, and as two 15lbs. weight cannot overbalance each other without either adding or diminishing, so a current of air cannot pass down one shaft and up another, but remains at a standstill, unless weight be added to or taken from the atmospheric pressure at the top of one of the shafts. You will now understand how a current of air is produced, and caused to pass down and around the workings of a mine.

As there are several ventilating powers, I will briefly mention a few of them:—

1. The force of the wind blowing on the surface is one power, because the air propelled into a hopper at the top of a shaft adds an increased weight or density in that shaft or scale, by which a current of air is produced for the workings.

2. A waterfall in one shaft propels a force of air which adds more weight to that scale, by which a current is produced.

3. A ventilating fan produces ventilation by its revolving force, because it adds to or diminishes the atmospheric weight,

and by so doing propels downwards or upwards a current of air for the workings.

4. The cylinder of a ventilating engine propels a force of air, up or down, with every stroke of the piston, which produces a current.

5. In giving an explanation of the furnace-power, I must return again to the subject of expansion and contraction, because the power of the furnace is in proportion to the amount of heat raised to the largest volume of cold air; therefore if we fill a bladder with say 480 cubic inches of the air at a temperature of 32 degrees, every degree of heat added to the air in the bladder would cause it to expand one part more, so that when the temperature had risen from 32 degrees to 152 degrees, the 480 parts of air would have expanded to 600 parts, or one-fifth larger, and the weight would be one-fifth less than in the space at first occupied.

By a simple illustration I think I can show this subject a little more clear. Suppose we had a pair of scales, and so large and so constructed, that we could weigh all the cold air in the down-cast shaft, and weigh in the other scale all the hot air that filled the up-cast; if so, we should find the cold air in the down-cast scale would overbalance very much the hot air in the up-cast scale. By this simple illustration you will now understand that the furnace heat swells out the air in the up-cast, by which it becomes much less in weight than the cold air in the down-cast for the space occupied; therefore, if one foot of cold air expands, by heat, into two feet, the two feet, you know, will only weigh the same weight as one foot before. Heat, then, makes air so light by expansion, that it rushes up one shaft like corkwood in water, or a balloon in the air, and the cold air in the down-cast is too

heavy to remain in its place, it falls down, and rushes through the workings to occupy the place of the hot air; therefore, to produce a great current of air, the furnace should be fixed where it can heat the largest volume of cold air, as its power is accordingly.

Before I leave this subject, I must tell you that the furnace power is affected much by changes of temperature on the surface, from winter to summer; because its power, as before stated, is in proportion to the number of degrees of heat raised betwixt the down and up-cast shafts; that is, if the furnace should raise the temperature in the up-cast to, say one hundred and forty-two degrees, at a time when on the surface the temperature was at, say thirty-two degrees, this will show a nett ventilating power of one hundred and ten degrees. But in summer if the temperature on the surface should rise to, say eighty degrees, the nett ventilating power of the furnace would be then only sixty-two degrees, because you take eighty from one hundred and forty-two; this will show that a change from winter to summer, or any sudden fall in temperature, affects much the furnace power and currents in mines.

By what I have now stated, you will understand when mines are in the greatest danger. When the barometer falls it shows that this weight in the atmospheric valve is diminished, by which an extra outlet of gases is discharged. Also, a rise in the thermometer shows an increased temperature on the surface, and, by this increased temperature, the ventilating power is diminished, by which the underground currents are also diminished: those two changes suddenly taking place at one and the same time, affect very much the workings of mines with gases. One is the cause of an extra discharge of gases; the other

diminishes that current of air which should take the gases away.

We now come to the subject of ventilation, or, to the distribution of the ventilating currents, a subject which has caused much controversy. To distribute the ventilating currents properly, for the safe conducting of gases through and out of the workings, requires the greatest caution and care; because the atmospheric changes are often and many; the opening and closing of doors, the up-lifting, squeezing, and falling of the air gates; together with the number of lights exposed, and sudden outlets of gases taking place, much caution and care is required, so that it is next to an impossibility to keep, at all times, every person away from danger; therefore, it is well, then, to keep as far as possible the danger from them, because there is a right and a wrong way of conducting gases away from the men, and out of the workings of a mine.

By ventilation, you may either throw all the gases discharged upon every workman employed, or conduct them away. I think I can make this subject a little more clear by a simple illustration. Suppose a number of chemical works are near a large population, who are affected by breathing impure air every time the wind blows from the works towards them, but in case a change in the wind takes place, so as to blow the gases in an opposite direction, if its force be not one-twelfth of that which blew the gases to them, yet, by this change of the wind, all will breathe a purer air, as no gas can come against the wind, be its velocity ever so small.

And so, in like manner, is the ventilation of mines; the ventilating current should be conducted pure into the workings, to convey, as far as possible, the gases away, and not conduct

them into the tramroads and upon every person employed. There are several ways of ventilation, but I propose to glance for a short time only at the separate current system; in doing . ask, what amount of air can be produced per minute for the whole workings of a mine? 20,000 feet, 40,000 feet, 60,000 feet, 80,000 feet, or 100,000 feet, be that amount less or more, all of it should not be sent in one current around the workings of a mine.

Divide or separate it into distinct currents, or parts, of say from 4,000 to 6,000 feet of pure air for each division; after which, if ten, fifteen, or twenty miners are getting coal in one district, supply the said number of miners with one distinct current of pure air, fresh from the down-cast, after which conduct the said current away safe to the up-cast, and do not, if possible, ventilate other workings with it afterwards. Then again, supply another current of fresh pure air to another group of miners, and conduct the said current as before, direct to the up-cast; and so on, in a similar manner, supply each party of miners with fresh distinct currents of pure air.

By splitting into parts you divide the explosive power, as gas is prevented by this system from collecting in large quantities, because, if one hundred feet of gas were discharged per minute from one group of miners, we might have five hundred feet discharged in the workings of five groups of miners, and to ventilate all with one current, the whole volume of five hundred feet of gas might be ignited at once; but not so if ventilated separately, only one-fifth would be ignited; if so, the power of the explosion would be reduced to one-fifth, the danger to a person's life reduced to one-fifth. Therefore, ventilate with separate currents. Yet do not misunderstand, and think I am of opinion there never

will be explosions; I answer, there always were and always will be explosions under the best management; yet, if a proper system of ventilation were adopted, the loss of life and property would not be so great when they do take place.

SUMMARY

OF A FEW

SERIOUS ACCIDENTS SINCE THE YEAR 1710.

DATE.	COLLIERY.	CAUSE.	LIVES LOST.
About 1710	Bensham	Exploded.	70 to 80
1743 Jan. 18	North Biddock	Do.	17
1757 June 10	Ravensworth	Do.	16
1766 Mar. 18	Walker	Do.	10
1767 Mar. 27	Fatfield	Do.	39
1778 Dec. 8	Dolly Pit, Chaytor's Haugh..	Do.	24
1794 June 9	Rickleton Pit, near Picktree	Do.	30
—— June 11	Harraton	Do.	28
1795 April 24	Paradise or West Pit, Benwell	Do.	11
1799 Oct. 11	Lumley	Do.	39
1803 Sept. 25	Wallsend	Do.	13
1805 Oct. 21	Hebburn	Do.	35
—— Nov. 29	Exclose	Do.	38
1806 Mar. 28	Killingworth	Do.	10
1809 Sept. 14	Killingworth	Do.	12
1812 May 25	Felling	Do.	92
—— Oct. 10	Herrington Mill Pit, Pensher	Do.	24
1813 Sept. 23	Hall Pit, Fatfield	Do.	32
—— Dec. 24	Felling	Do.	22
1814 Aug. 12	Hebburn	Do.	11
1815 May 3	Heaton Main	Inundation	75
—— June 2	Success Pit, Newcastle	Exploded	57
—— June 27	Sheriff Hill	Do.	11
1817 June 30	Row Pitt, Harraton	Do.	38
—— Dec. 18	Plain Pit, Rainton	Do.	27
1819 July 19	Sheriff Hill	Do.	35
—— Oct. 9	George Pit, Lambton	Do.	13
1821 Oct. 28	Wallsend (Russell's)	Do.	52
1823 Nov. 3	Plain Pit, Rainton	Do.	59
1824 Nov. 19	Dolly Pit, Newbottle	Do.	11
—— Oct. 25	George Pit, Lumley	Do.	14
1825 July 3	Judith Pit, Fatfield	Do.	11
1826 Jan. 17	Jarrow	Do.	34

DATE.			COLLIERY.	CAUSE.	LIVES LOST.
1826	May	30	Townley	Exploded	38
1826	Nov.	20	1 Pit, Washington	Do.	14
1830	Aug.	3	Jarrow	Do.	42
1833	May	9	Springwell	Do.	47
1835	June	18	Wallsend	Do.	102
1836	Jan.	28	Hetton Colliery	Do.	20
1839	June	28	Hilda Wallsend, South Shields	Do.	50
1840	Jan.	24	*Rothwell Haigh, Leeds	Do.	7
1844	Sept.	28	Haswell	Do.	95
1845	Aug.	21	Jarrow Colliery	Do.	39
1850	Nov.	11	Houghton	Do.	26
1851	Mar.	15	Nitshill, Scotland	Do.	61
——	Aug.	19	Washington	Do.	28
——	Oct.	31	Killingworth	Do.	9
——	Dec.	20	Warren Vale Colliery, Rotherham	Do.	52
1852	May	—	Hebburn	Do.	23
1853	Mar.	24	Ince Hall Arley Mine, Wigan	Do.	58
——	April	26	Old Park Colliery, Dudley	Do.	11
——	July	1	Bent Grange Colliery, Oldham	Do.	20
1855		—	Middle Duffryn	Do.	68
1856		—	Cymmer Colliery	Do.	114
1857	Feb.	19	Lund-hill	Do.	189
1860	Mar.	2	Burradon	Do.	74
——	Dec.	7	Risca, South Wales	Do.	130
——	Dec.	20	Hetton	Do.	22
1861	July	—	Clay Cross	Inundated	23
1862	Jan.	16	Hartley	By breaking of engine pump beam.	204
——	Mar.	—	Gethin	Exploded	47
——	June	2	Bilston	Inundated	7
——		—	Washington	Exploded	28
——		—	Guindraeth, South Wales	Do.	27
——		—	Coppul	Do.	36
1866		—	Bedwellty Colliery	Do.	21
——	Dec.	12, 13	Oaks Colliery	Do.	362
——	Dec.	13	Talk-o'th'-Hill	Do.	91
1867	Nov.	8	Ferndale Colliery	Do.	17

* At this colliery, Rothwell Haigh, near Leeds, the father of William Hopton, the author of this book, was lost.

USEFUL TABLES.

Weights and Measures.

The origin of all *Weights and Measures* in England was derived from a grain of wheat; vide statutes of 51 Henry III., 31 Edward I., and 12 Henry VII., which enacted that 32 of them, well dried, and gathered from the middle of the ear, were to make 1 pennyweight; 20 dwts. 1 oz.; and 20 oz. 1 pound.

It was subsequently thought better to divide the *pennyweight* into 24 equal parts, called *grains*.

William the Conqueror introduced into England what was called TROY WEIGHT, from Troyes, a town in the province of Champagne, in France (now in the department of Aube), where a celebrated fair was held. The English were dissatisfied with this weight, because the pound did not weigh so much as the pound in use at that time in England. Hence arose the term, *Avoir du poids*, which was a medium between the French and the ancient English weights.

AVOIRDUPOIS WEIGHT was first made legal in the reign of Henry VII., and its particular use was to weigh provisions and coarse heavy articles. Henry fixed the stone at 14lbs., which has been confirmed by a recent Act of Parliament.

With respect to MEASURES OF LENGTH, it is recorded that the various denominations were constructed from *a corn of barley*, 3 of which, well dried, from the middle of the ear, made an inch. Other terms were taken from portions of the human body, such as the *Digit* ($\frac{3}{4}$ of an inch, or a finger's breadth), a *Palm* (3 inches), a *Hand* (4 inches), a *Span* (9 inches), a *Foot* (12 inches), and a *Cubit* (18 inches), being the length of the arm or bone from the elbow to the wrist. A *Pace* (5 feet), or 2 ordinary steps; a *Fathom* (6 feet), from the extremity of one hand to that of the other, the arms are oppositely extended. It is stated that Henry I., in 1101, commanded that the ulna, or ancient ell, which answers to the modern yard, should be made the length of his arm; and that the other measures of length were hence derived, whether *lineal*, *superficial*, or *solid*.

All MEASURES OF CAPACITY were first taken from Troy Weight, and several laws were passed in the reign of Henry III., enacting that 8lbs. Troy of wheat, taken from the middle of the ear and well dried, should make one gallon of Wine measure, and 8 such gallons make a bushel.

Weights and measures were invented 869 B.C.; fixed to a standard in England, A.D. 1257; regulated, 1492; equalised, 1826, *agreeable to the Act of Uniformity which took effect 1st Jan.*, 1826.

The term *Measure* may be distinguished into several kinds. viz:—*Length, Surface, Volume, Specific Gravity, Capacity, Space, and Time and Motion.*

The several Denominations of these Measures have reference to certain *standards*, which are entirely arbitrary, and consequently vary among different nations. In this kingdom the *standard* of

Length is a *Yard*.
Solidity is a *Cubic Yard*.
Surface is a *Square Yard*, the $\frac{1}{4840}$ of an acre.
Capacity is a *Gallon*.
Weight is a *Pound*.

The standards of *Angular Measure* and of *Time* are the same in all European and most other countries.

The *Imperial Standard Yard* and the *Imperial Standard Pound Troy* having been destroyed in the fire at the Houses of Parliament in 1834, *Restored Standards of Weights and Measures* have been legalised by 18 and 19 Vic., cap. 72.

1.—Measures of Length.

The *Restored Standard* of Lineal Measure, whose length is called a yard, is a solid square Bar, thirty-eight inches long and one inch square, in transverse section, the Bar being of bronze or gun metal, at the temperature of 62 deg. of Fahrenheit's Thermometer—marked Copper 16 oz., Tin 2½ oz., Zinc 1 oz.—and near to each end a cylindrical hole is sunk, to the depth of half-an-inch; the distance between the centres of the two holes being 3 *Feet*, or 36 inches, or one *Imperial Standard Yard*. The standard *square* and *cubic* measures will therefore depend entirely upon it.

At present we have no means of ascertaining why this particular length was originally fixed upon; but, as it is most essential that it should always remain the same, it will be found convenient to refer it to something else, which we have no reason to suppose ever undergoes any change.

Now the length of a *Pendulum* vibrating *seconds*, or performing 46,400 oscillations in the interval between the sun's leaving the meridian of a place and returning to it again, is always the same at a *fixed* place, and under the *same* circumstances; and if this length be divided into 391,392 equal parts, the yard is *defined* to be equivalent to 360,000 of these parts; also, conversely, since a yard is equal to 36 inches, it follows that the length of the seconds pendulum, expressed in inches, is 39·1392.

The *Pendulum* referred to in this country is one vibrating seconds at *Greenwich* or in *London*, at the level of the sea in a non-resisting medium; and if the *standard yard* be at any time lost or destroyed, it would be easy to have recourse to experiment for its recovery.

The *Standard Yard* being the general *Unit* of lineal measure, it follows that all lengths less than a *yard* will be expressed by fractions; and it is on this account that a lineal *inch*, or *ten thousand* of the aforesaid portions of the *pendulum*, is conveniently adopted as the *unit* of lineal measure when applied to small magnitudes.

Hence also, by the same means, the *standard superficial* and *solid* measures will be accurately ascertained and kept correct.

LINEAL MEASURE.

12	Inches	=	1	Foot (ft).
3	Feet	=	1	Yard (yd).
5½	Yards	=	1	Rod or Pole (p).
40	Poles, or 220 yards	=	1	Furlong
8	Furlongs, or 1760 yards	=	1	Mile.

By this measure are computed the lineal dimensions of all magnitudes with the exception mentioned below.

The *length* of a mile is not the same in every country. The Scotch and Irish miles were formerly about 1¼ miles English, but are now the same as English. A Spanish and Polish mile is about 3½ English. A Swedish, Danish, and Hungarian mile is from 5 to 6 English miles. A Russian, mile or verst is about ¾ of an English mile, and the French toise is about 6 feet.

The Dutch mile	=	8101 Yards	
Roman	=	1628	„
Arabian	=	2148	„
Persian Parasang	=	6086	„
1 1/12 Inches	=	1 Line	
⅓ Inch	=	1 Barleycorn	
3 Inches	=	1 Palm	
4 Inches	=	1 Hand.*	
7 9/25 Inches	=	1 Link.	
9 Inches	=	1 Span.	
18 Inches	=	1 Cubit.	
2½ Feet	=	1 Pace.†	
5 Feet	=	1 Geometrical Pace.	
6 Feet	=	1 Fathom.‡	
5½ Yards	=	1 Rod, Pole, or Perch.	
4 Poles, or 22 Yards	=	1 Chain.	
3 Miles	=	1 League.	
60 Geographical miles, or 69½ English miles	=	1 Degree (or °).	
360 Degrees	=	The circumference of the Globe, or any Circle	

CLOTH MEASURE.

This measure is used for all kinds of cloth, muslin, ribbon, &c.

The *Yard* in Cloth measure is the same as in Long Measure, but differs in its divisions and sub-divisions.

* The *Hand* is used for measuring the height of horses.

† The *Pace* is a measure taken from the space between the two feet of a man in walking, usually reckoned at 2½ feet, but the *Geometrical Pace* is 5 feet.

‡ The *Fathom* is used in sounding to ascertain depth, &c., and for measuring cordage.

2¼	Inches	=	1 Nail.
4	Nails	=	1 Quarter.
4	Quarters	=	1 Yard.
3	Quarters	=	1 Flemish Ell.
5	Quarters	=	1 English Ell.
6	Quarters	=	1 French Ell.

II.—Measures of Surface.

The *Imperial Square Yard* contains 9 imperial square feet, and the *Imperial Square Foot*, 144 imperial square inches; the *Circular Foot* (that is, a circle whose diameter is 1 foot) contains 113·027 square inches; and the *Square Foot* contains 183·346 circular inches (that is, circles whose diameters are each 1 inch).

SUPERFICIAL MEASURE.

144	Sq. Inches	=	1 Sq. Foot.
9	Sq. Feet	=	1 Sq. Yard.
30¼	Sq. Yards	=	1 Sq. Pole.

This measure is used for all kinds of superficial measuring, such as land, paving, flooring, roofing, tiling, slating, plastering, &c., and anything having length and breadth only.

Flooring, roofing, thatching, &c., are measured by the square of 100 feet, and bricklayers' work by the pole of 16½ feet, the square of which is 272¼ feet, though this is partly a cubic measure, as the brickwork is reckoned to be 14 inches, or 1½ brick thick.

LAND MEASURE.

40 Sq. Poles		=	1 Sq. Rood.
9 Sq. Roods, or 4840 Sq. Yards		=	1 Sq. Acre.
640 Sq. Acres		=	1 Sq. Mile.
30 Sq. Acres		=	1 Yard of Land.
100 Sq. Acres		=	1 Hide of Land.
40 Hides		=	1 Barony.

The dimensions of land, or of any surface of considerable extent, are taken by means of *Gunter's Chain*, which is 4 poles or 22 yards in length, and is divided into 100 equal parts, called *links*.

III.—Measures of Volume.

The *Imperial Cubic* (or solid) *Yard* contains 27 imperial cubic feet and the *Imperial Cubic Foot* contains 1728 imperial cubic inches. The *Cylindrical* foot (that is, a cylinder 1 foot long and 1 foot in diameter) contains 1357·17 cubic inches. The *Spherical* foot (that is, a sphere 1 foot in diameter) contains 904·78 cubic inches: and a *Conical* foot (that

is, a cone 1 foot in height and 1 foot in diameter at the base) contains 452·39 cubic inches. The *Cubic* foot contains very nearly 2200 cylindrical inches (that is, cylinders 1 inch long and 1 inch in diameter); it contains very nearly 3300 spherical inches (that is, spheres 1 inch in diameter); and it contains very nearly 6600 conical inches (that is, cones 1 inch in height and 1 inch in diameter at the base).

SOLID OR CUBIC MEASURE.

A *Cube* is a solid body, and contains length, breadth, and thickness: having six equal sides. A *Cube number* is produced by multiplying a number twice into itself; thus, 64 is a cube number, and is produced by multiplying the number twice into itself, as 4 x 4 x 4 = 64.

1728 Cubic Inches	=	1 Cubic Foot.
27 Cubic Feet	=	1 Cubic Yard.
40 Cubic Feet of Rough or 50 Cubic Feet of Hewn Timber	=	1 Ton or Load.
42 Cubic Feet of Timber	=	1 Shipping Ton.
108 Cubic Feet	=	1 Stack of Wood.
128 Cubic Feet	=	1 Cord of Wood.

IV.—Standard of Specific Gravity.

WEIGHT AND MEASURE OF WATER AT THE COMMON TEMPERATURE.

1 pint=34·65 cubic inches, or 1·25lbs.
1 gal=277·274 cubic inches, or 10lbs.
11·2 gals.=1 cwt.
224 gals.=1 ton.
1 cubic inch=252·45 grs., or ·03617 lbs.
12 „ inches=434 lbs.
1 „ foot=6·25 gals., or 1000 ozs., or 62·5 lbs.
1·8 „ „ =1 cwt.
35·84 cubic feet=1 ton.
1 cylindrical inch=·02842 lbs.
12 „ inches=·341 lbs.
1 „ foot=5 gals., or 49·1 lbs.
2·282 „ feet=1 cwt.
45·64 „ „ =1 ton.
1 cubic inch of mercury 34 25·25 grs.

The *Imperial pound avoirdupois*, which is the standard unit by means of which all heavy goods of large masses are weighed, is *defined* to be the weight of *one-tenth* part of an imperial gallon, or 27·7274 cubic inches of distilled water, ascertained at a time when the barometer stands at 30 deg., and the height of *Fahrenheit's* thermometer is 62 deg.; and this standard may consequently be verified or recovered at any time, when it may be necessary to appeal to experiment.

If the weight of a cubic inch of distilled water be divided in 505 equal parts, and each of such parts be defined to be a *half-grain*, it follows that 27·7274 cubic inches contain very nearly 7000 such grains; and it is hence declared by Act of Parliament that 7000 *grains* exactly shall hereafter be considered as the *pound* avoirdupois; and that 10 *grains* shall be equivalent to 1 *scruple;* and 3 *scruples* to 1 *drachm;* but the latter denominations are seldom necessary unless great nicety be required.

This weight receives its name from *avoirs*, the ancient name for *goods and chattels*, and *pois* signifying *weight*, in the ordinary language of the country at the time of the *Normans*.

The *Restored Imperial Standard Pound Avoirdupois*, is constructed of Platinum, the Form being that of a *Cylinder* nearly 1·35 inch in height, and 1·15 inch in diameter, marked P.S., 1844, 1 lb.

DIVISION 1.—AVOIRDUPOIS WEIGHT.

27 11/22	Grains	= Drachm..... =	27 11/22	grains.
16	Drachms	= 1 Ounce..... =	437½	„
16	Ounces	= 1 Pound (lb.) =	7000	„
14	Pounds	= 1 Stone.		
28	Pounds	= 1 Quarter (qr.)		
4	Quarters	= 1 Hundred weight (cwt.)		
20	Cwt.	= 1 Ton.		

This weight is used in almost all commercial transactions, and in all the common dealings of life.

By an Act of Parliament passed the 5th of October, 1831, and which came into effect on the 1st of January, 1832, it is directed that all coals, cinders, and culm, sold from and out of any ship or vessel in the port of London; or at any place within the cities of London and Westminster, or within the distance of 25 miles from the General Post Office, in the city of London, should be sold by weight and not by measure.

Coals sold in any quantity exceeding 500 lbs., are to be delivered to the purchaser in sacks containing either 112 lbs. or 224 lbs. net; 10 such sacks, or 2240 lbs., make a ton, equal to 20 cwt.; 25½ cwt. are equivalent to 1 chaldron. A barge load, or keel, is 21 tons, 4 cwt.; and a collier, or ship load, about 20 such keels, or 424 tons.

By an Act of Parliament, which came into effect on the 29th of September, 1822, bread must be sold by the pound avoirdupois, and bakers are prohibited from selling by the peck-loaf with its subdivisions.

Flour is sold nominally by measure, but actually by weight, at 7 lbs. avoirdupois to a gallon, 14 lbs. to a peck, &c.

By a late Act of Parliament, the legal stone is, in all cases, to consist of 14 lbs. avoirdupois; 8 such stone 1 cwt.; 20 cwt. 1 ton.

V.—Measures of Space.

A *Circle* contains 360 degrees; a *Degree* 60 minutes; a *Minute*, 60 seconds, &c.; consequently a *Semi-circle* contains 180 degrees; a *Quadrant*, 90 degrees; a *Sextant*, 60 degrees; and an *Octant*, 45 degrees; a *right angle* contains, or is measured by 90 degrees, and two right angles by 180

degrees. The *circumference* of a circle is nearly $3\frac{1}{8}$ times its diameter, or more accurately 3·1416 times; in other words, this number is the *circumference* of a circle, whose *diameter* is unity; consequently the *diameter* of a circle is nearly 7·22, or more accurately ·31831 of its circumference. In France the *circle* is frequently divided into 400 degrees, a degree into 100 minutes, and a minute into 100 seconds, &c. The latter is called the *centesimal* system, and the former the *sexagesimal;* consequently, 1 centesimal degree contains 54 sexagesimal minutes; 1 centesimal minute, 32·4 sexagesimal seconds; 1 centesimal second, ·324 of a sexagesimal second; and also 1 sexagesimal degree contains $1\frac{1}{8}$ centesimal degree; 1 sexagesimal minute, 1·85185 centesimal minutes; and 1 sexagesimal second, 3·08641 centesimal seconds. A mean *sexagesimal* degree of the terrestrial meridian measurse 69·045 imperial miles.

ANGULAR MEASURE, OR DIVISIONS OF THE CIRCLE.

60 Seconds	= 1	Minute.
60 Minutes	= 1	Degree.
30 Degrees	= 1	Sign.
90 Degrees	= 1	Quadrant.
4 Quadrants	= 1	Circle.
360 Degrees, or 12 Signs.	= 1	Circumference or circle.

VI.—Measures of Time and Motion.

A *Mean Solar Day* is the mean apparent time of one revolution of the earth on its axis; and is divided into 24 hours; an hour into 60 minutes; and a minute into 60 seconds, &c.; hence the mean daily apparent motion of the sun is 15 degrees per hour, or 1 degree in 4 minutes of time. A *Sidereal Day* is the real and invariable period of the diurnal rotation, and contains 23 hours, 56 minutes, $4\frac{1}{10}$ seconds of mean solar time. A *Tropical Year* is the period of one revolution of the earth in its orbit, and contains 365 days, 5 hours, 48 minutes, 49·19 seconds of mean solar time. The seconds pendulum makes 86,400 vibrations in a mean solar day at the same place on the earth's surface.

DECIMALS OF A FOOT AND A SHILLING.

1	=	·083333
2	=	·166666
3	=	·25
4	=	·333333
5	=	·416666
6	=	·5
7	=	·583333
8	=	·666666
9	=	·75
10	=	·833333
	=	·916666

To find the area of [illegible] ultiply diame[illegible] gain by 7854.

To find the cir[illegible] ply 3·141[illegible]

Weight of Coal in Tons per Acre, from 1 inch thick to 12 feet 11 inches.

1	2	3	4	5	6	7	8	9	10	11
126·60	253·20	379·81	506·41	633·02	759·62	886·23	1012·03	1139·44	1266·04	1392·64
1645·80	1772·40	1899·00	2025·60	2152·27	2278·87	2405·48	2532·08	2658·69	2785·29	2911·89
3164·99	3291·59	3418·19	3544·79	3671·39	3797·99	3924·73	4051·33	4177·94	4304·54	4431·14
4684·33	4810·93	4937·53	5064·13	5190·77	5317·37	5443·98	5570·58	5697·19	5823·79	5950·39
6203·67	6330·27	6456·87	6583·47	6710·07	6836·67	6963·28	7089·88	7216·44	7343·04	7469·64
7723·01	7849·61	7976·21	8102·81	8229·41	8356·01	8482·62	8609·08	8735·69	886229	8988·89
9242·35	9368·95	9495·55	9622·15	9748·75	9875·35	10001·96	10128·56	10254·95	10381·55	10508·15
10761·69	10888·29	11014·89	11141·49	11268·09	11394·69	11520·00	11647·50	11774·20	11900·80	12027·40
12281·03	12407·63	12534·23	12660·83	12787·43	12914·03	13040·64	13166·84	13293·45	13420·05	13546·65
13800·37	13926·97	14053·57	14180·17	14306·77	14433·37	14559·98	14686·10	14812·71	14939·31	15065·91
15319·71	15446·31	15572·91	15699·51	15826·11	15952·71	16078·78	16205·38	16331·96	16458·56	16585·16
16839·05	16965·65	17092·25	17218·85	17344·79	17471·39	17598·00	17724·60	17851·21	17977·81	18104·41
18358·39	18484·99	18611·59	18737·49	18864·04	18990·64	19117·25	19243·85	19370·46	19497·06	19623·66

CALCULATED FOR A SPECIFIC GRAVITY OF 1·25.

TABLE SHOWING QUANTITY OF WATER, IN IMPERIAL GALLONS, DELIVERED BY A PUMP AT EACH STROKE OF THE ENGINE (CONTINUED).

Dia. of Pump in inches.	LENGTH OF STROKE.					
	4ft. 6in.	5ft. 0in.	5ft. 6in.	6ft. 0in.	6ft. 6in.	7ft. 0in.
3	1·37	1·52	1·68	1·83	1·97	2·13
4	2·44	2·72	2·99	3·26	3·53	3·80
5	3·82	4·25	4·67	5·10	5·52	5·95
6	5·50	6·11	6·73	7·34	7·95	8·56
7	7·49	8·32	9·16	9.99	10·81	11·65
8	9·78	10·87	11·96	13·05	14·13	15·22
9	12·38	13·76	15·14	16·52	17·89	19·27
10	15·30	17·00	18·70	20·40	22·10	23·80
11	18·50	20·55	22·62	24·67	26·72	28·78
12	22·02	24·47	26·92	29·37	31·81	34·26
13	25·85	28·72	31·59	34·47	37·33	40·21
14	29·97	33·30	36·64	39·97	43·29	46·63
15	34·41	38·23	42·06	45·89	49·70	53·53
16	39·16	43·51	47·86	52·22	56·57	60·92
17	44·21	49·12	54·03	58·95	63·85	68·77
18	49·55	55·06	60·57	66·08	71·58	77·09
19	55·21	61·35	67·48	73·62	79·75	85·89
20	61·18	67·98	74·78	81·58	88·38	95·18
21	67·45	74·95	82·44	89·94	97·43	104·93
22	74·03	82·26	90·49	98·72	106·95	115·17
23	80·91	89·90	98·90	107·89	116·87	125·87
24	88·11	97·90	107·69	117·48	127·27	137·06
25	95·60	106·22	116·85	127·47	138·08	148·71
26	103·41	114·90	126·39	137·88	149·37	160·86
27	111·51	123·90	136·30	148·69	161·07	173·47
28	119·93	133·25	146·58	159·91	173·23	186·56
29	128·65	142·95	157·24	171·54	185·83	200·13
30	137·67	152·97	168·27	183·57	198·86	214·16
31	147·00	163·33	179·67	196·01	212·33	228·67
32	156·64	174·05	191·45	208·86	226·26	243·67
33	166·59	185·10	203·61	222·12	240·63	259·14
34	176·83	196·48	216·13	235·79	255·43	275·08
35	187·39	208·21	229·03	249·86	270·68	291·50
36	198·24	220·27	242·30	264·33	286·35	308·38

TABLE SHOWING QUANTITY OF WATER, IN IMPERIAL GALLONS, DELIVERED BY A PUMP AT EACH STROKE OF THE ENGINE (CONTINUED).

Dia. of Pump in inches.	LENGTH OF STROKE.					
	7ft. 6in.	8ft. 0in.	8ft. 6in.	9ft. 0in.	9ft. 6in.	10ft. 0in.
3	2·28	2·45	2·59	2·74	2·89	3·06
4	4·07	4·35	4·61	4·89	5·16	5·44
5	6·37	6·80	7·22	7·65	8·07	8·50
6	9·17	9·79	10·39	11·00	11·61	12 23
7	12·48	13·32	14·15	14·98	15·81	16·65
8	16·31	17·40	18·48	19·57	20·65	21 75
9	20·64	22·03	23·39	24·77	26·14	27·53
10	25·50	27·20	28·90	30·60	32·30	34·00
11	30·84	32·90	34·95	37·00	39·05	41·12
12	36·71	39·16	41·60	44·05	46·49	48·95
13	43·08	45·96	48·83	51·70	54·57	57·45
14	49·96	53·30	56·62	59·95	63·27	66·62
15	57·35	61·19	65·00	68·82	72·64	76·48
16	65·27	69·62	73·97	78·32	82·67	87·02
17	73·68	78·60	83·51	88·42	93·33	98·25
18	82·59	88·11	93·60	99·11	104·61	110·13
19	92·02	98·17	104·29	110·43	116·56	122·71
20	101·98	108·78	115·57	122·37	129·16	135·97
21	112·42	119·93	127·41	134·91	142·40	149·91
22	123·40	131·63	139·84	148·07	156·29	164·53
23	134·86	143·86	152·84	161·83	170·81	179·82
24	146·85	156·65	166·43	176·22	186·01	195·81
25	159·33	169·97	180·58	191·22	201·82	212·46
26	172·35	183·85	195·33	206·82	218·31	229·81
27	185·86	198·26	210·64	223·03	235·41	247·82
28	199·89	213·22	226·54	239·86	253·18	266·52
29	214·42	228·72	243·01	257·31	271·16	285·90
30	229·46	244·76	260·05	275·35	290·64	305·95
31	245·00	261·35	277·67	294·00	310·33	326·68
32	261·07	278·48	295·88	313·29	330·69	348·10
33	277·65	296·16	314·67	333·18	351·69	370·20
34	294·73	314·39	334·02	353·67	373·31	392·98
35	312·32	333·15	353·96	374·78	395·60	416·43
36	330·41	352·44	374·46	396·49	418·51	440·55

TABLE OF INCLINE MEASURE.

Showing the comparative lengths of the three legs of a right-angled triangle, likewise the gravity due to incline, and the number of square yards in an acre, &c., for every degree of the quadrant, for various practical uses, as per explanations following:—

No. of Degrees. 1.	Inclination per Yard in inches. 2.	One in 3.	Horizontal Measure, Hypothenuse being 1 — 4	Vertical Measure, Hypothenuse being 1 — 5.	Deduct links per Chain. 6.	Gravity due to Incline per ton, in lbs. 7.	Square Yards per Acre. 8.	No. of Degrees 9.
1	0·63	57·29	·99985	·01745	0·01	39·08	4840·72	1
2	1·26	28·63	·99939	·03490	0·06	78·18	4842·95	2
3	1·88	19·09	·99863	·05234	0·14	117·24	4846·63	3
4	2·51	14·29	·99756	·06976	0.24	156·26	4851·83	4
5	3·15	11·42	·99619	·08716	0.38	195·62	4858·51	5
6	3·78	9·51	·99452	·10453	0.55	234·14	4866·66	6
7	4·42	8·14	·99255	·12187	0·74	272·98	4876·32	7
8	5·06	7·11	·99027	·13917	0·97	311·74	4887·55	8
9	5·70	6·31	·98769	·15643	1·23	350·40	4900·32	9
10	6·34	5·67	·98481	·17365	1·52	388·97	4914·65	10
11	6·99	5·14	·98163	·19081	1·84	427·41	4930·57	11
12	7·65	4·70	·97815	·20791	2·19	465·71	4948·11	12
13	8·31	4·33	·97437	·22495	2.56	503·88	4967·31	13
14	8·97	4·01	·97030	·24192	2·97	541·90	4988·14	14
15	9·64	3·73	·96593	·25882	3·40	579·75	5010·71	15
16	10·32	3·48	·96126	·27564	3·87	617·43	5035·05	16
17	11·00	3·27	·95630	·29237	4·37	654·90	5061·17	17
18	11·69	3·07	·95106	·30902	4·89	692·20	5089·05	18
19	12·39	2·90	·94552	·32557	5·45	729·27	5118·87	19
20	13·10	2·74	·93969	·34202	6·03	766·12	5150·63	20
21	13·82	2·60	·93358	·35837	6·64	802·74	5184·34	21
22	14·54	2·47	·92718	·37461	7·28	839·12	5220·12	22
23	15·27	2·35	·92050	·39073	7·95	875·23	5258·01	23
24	16·02	2·24	·91355	·40674	8·65	911·09	5298·01	24
25	16·78	2·14	·90631	·42262	9·37	946·66	5340·33	25
26	17·56	2·05	·89879	·43837	10·12	981·94	5385·01	26
27	18·34	1·96	·89101	·45399	10·90	1016·93	5132·03	27
28	19·14	1·88	·88295	·46947	11·71	1051·61	5481·62	28
29	19·95	1·80	·87462	·48481	12·54	1085·97	5533·83	29
30	20·78	1·73	·86602	·5	13·40	1120·00	5588·78	30
31	21·62	1·66	·85717	·51504	14·28	1153·68	5646·48	31
32	22·49	1·60	·84805	·52992	15·19	1187·02	5707·21	32
33	23·37	1·54	·83867	·54464	16·13	1219·99	5771·04	33
34	24·28	1·48	·82904	·55919	17·10	1252·58	5838 07	34
35	25·20	1·42	·81915	·57358	18·08	1284·81	5908·56	35
36	26·15	1·37	·80902	·58778	19·10	1316·62	5982·54	36
37	27·12	1·32	·79864	·60181	20·14	1348·05	6060·30	37
38	28·12	1·28	·78801	·61566	21·20	1379·07	6142·05	38
39	29·14	1·23	·77715	·62932	22·28	1409·67	6228·01	39
40	30·21	1·19	·76604	·64279	23·40	1439·84	6318·20	40
41	31·29	1·15	·75471	·65606	24·53	1469·57	6413·05	41
42	32·41	1·11	·74314	·66913	25·69	1498·85	6512·90	42
43	33·56	1·07	·73135	·68200	26·86	1527·68	6617·89	43

TABLE OF INCLINED MEASURE (CONTINUED).

No. of Degree.	Inclination per Yard in Inches.	One in	Horizontal Measure, Hypothenuse being 1.	Vertical Measure, Hypothenuse being 1.	Deduct links per Chain.	Gravity due to Incline per ton in lbs.	Square Yards per Acre.	No. of Degree.
1.	2.	3.	4.	5.	6.	7.	8.	9.
44	34·76	1·03	·71934	·69466	28·07	1556·03	6728·38	44
45	36·00	1·00	·70711	·79711	29·29	1583·92	6844·76	45
46	37·27	·96	·69466	·71934	30·53	1611·32	6967·43	46
47	38·60	·93	·68200	·73135	31·80	1638·22	7096·77	47
48	39·98	·90	·66913	·74314	33·09	1664·63	7233·27	48
49	41·41	·87	·65606	·75471	34·39	1690·55	7377·37	49
50	42·90	·84	·64279	·76604	35·72	1715·92	7529·67	50
51	44·46	·81	·62932	·77715	37·07	1740·81		51
52	46·07	·75	·61566	·78801	38·43	1765·14		52
53	47·77	·73	·60181	·79864	39·82	1788·95		53
54	49·54	·70	·58778	·80902	41·22	1812·20		54
55	51·41	·67	·57358	·81915	42·64	1834·89		55
56	53·36	·65	·55919	·82904	44·08	1857·04		56
57	55·44	·62	·54464	·83867	45·54	1878·62		57
58	57·61	·62	·52992	·84805	47·01	1899·63		58
59	59·92	·60	·51504	·85717	48·50	1920·06		59
60	62·35	·58	·5	·86602	50·00	1939·88		60
61	64·94	·55	·48481	·87462	51·52	1959·14		61
62	67·69	·53	·46947	·88295	53·05	1977·80		62
63	70·65	·51	·45399	89101	54·60	1995·86		63
64	73·80	·49	·43837	·89879	56·16	2013·28		64
65	77·20	·47	·42262	·90631	57·74	2030·13		65
66	80·86	·45	·40674	·91355	59·33	2046·35		66
67	84·81	·42	·39073	·92050	60·93	2061·92		67
68	89·10	·40	·37461	·92718	62·54	2076·88		68
69	93·77	·38	·35837	·93358	64·16	2091·21		69
70	98·91	·36	·34202	·93959	65·80	2104·90		70
71	104·53	·34	·32557	·94552	67·44	2117·96		71
72	110·80	·32	·30902	·95106	69·10	2130·37		72
73	117·73	·31	·29237	·95630	70·76	2140·11		73
74	125·56	·29	·27564	·96126	72·44	2153·22		74
75	134·37	·27	·25882	·96593	74·12	2163·68		75
76	144·40	·25	·24192	·97030	75·81	2173·47		76
77	155·90	·23	·22495	·97437	77·50	2182·58		77
78	169·36	·21	·20791	·97815	79·21	2191·05		78
79	185·20	·19	·19081	·98163	80·92	2198·85		79
80	204·10	·18	·17365	·98481	82·63	2205·97		80
81	227·34	·16	·15643	·98769	84·36	2212·42		81
82	256·11	·14	·13917	·99027	86·08	2218·20		82
83	293·13	·12	·12187	·99253	87·81	2223·26		83
84	342·60	·10	·10453	·99452	89·55	2227·72		84
85	411·27	·09	·08716	·99619	91·28	2231·46		85
86	514·52	·07	·06976	·99756	93·02	2234·53		86
87			·05234	·99863	94·77	2236·93		87
88			·03490	·99939	96·51	2238·63		88
89			·01745	·99985	98·25	2239·66		89

It is obviously unnecessary to give this above (about) 80 degrees.

REMARKS ON THE CONSTRUCTION AND APPLICATION OF THE FOREGOING TABLE.

COLUMN 1.—This is the amount of the angle which inclined planes make with the horizon, and is found sometimes with the compass-cover and a small plummet, more correctly with a quadrant attached to the compass for the purpose, but more accurately by a theodolite.

COLUMN 2 gives the expression of the amount of elevation in phraseology more familiar to many colliery agents than "degrees," for, when speaking of the amount of the rise of underground roads, they generally say they rise so much per yard.

COLUMN 3.—This is only another way of expressing the amount of the gradient, and is obtained by dividing the horizontal measure by the vertical rise.

COLUMN 4.—The figures given in this column show the length of the cosine, radius being unity; or, in other words, the length of the base of a right-angled triangle, the hypothenuse being one. Therefore, in order to obtain the length of the horizontal measure, when the hypothenuse and angle have been obtained, say:

As 1 : cosine : : hypothenuse : base; or multiply the hypothenusal measure by the figures in this column, and the result will be the horizontal measure.

EXAMPLE: I took a sight up an incline rising 35 deg., and the distance on the slant was 870 links; what is the horizontal measure—what is the proper distance to be plotted?

Opposite 35 in the the fourth column I find ·81915; this multiplied by 870 = 712·66, or 712⅔ links nearly.

The same result may be obtained by deducting the proper number of links per chain as given in column 6.

COLUMN 5.—The figures in this column show the length of the sine, radius being one, or the length of the perpendicular of a right-angled triangle, hypothenuse being unity; therefore to ascertain the amount of rise on an incline, the elevation and slant distance being given, say,

As 1 : sine : : hypothenuse : perpendicular; or multiply the slant measure by the figures in this column opposite the number of degrees.

EXAMPLE: What is the vertical rise of an incline whose angle is 36 deg., and slant distance 400 links?

400 x ·58778 = 235·112 links,

or, 235·112 x 7·92 = 155ft. 2in.

For an explanation of the manner of forming a table of natural sines, cosines, &c., see any treatise on plane trigonometry.

It may be asked why we have extended the table beyond 45 deg., when it is so well understood that the cosines of 46 deg., 47 deg., 48 deg., &c., are always the same as the sines of 44 deg., 43 deg., 42 deg., &c., respectively. We think that by doing so we simplify matters, and besides it is necessary for showing the figures in columns 2, 3, 6, 7, and 8.

COLUMN 6.—The number of links to be deducted in a chain, given in this column, has been found thus:

$$100 - \frac{\text{Cosine} \times 100}{1};$$

and the reason will be apparent from what has already been said.

COLUMN 7.—A body on an inclined plane will be supported by a weight which bears the same proportion to it that the height does to the length of the plane. Thus, at an angle of 28 deg., we have the length and height of the plane in the proportion of 1 to ·46947, therefore the weight that would support, say 2,240lbs., at this angle would be

As 1 : ·46947 :: 2240 : 1051·61.

This is what we have called the "gravity due to incline" in the table. The weight shown has been obtained by multiplying the number of pounds in a ton by the sine of the different angles. These figures will be found of some use in the case of slants, where, for instance, coal is pulled up an inclined plane by means of a stationary engine and a rope.

EXAMPLE: The weight of the tubs, coals, rope, &c., which is pulled up a slant whose angle is 26 deg., amounts to 70 cwt: to how much weight is this equivalent pulled up vertically, or what is the working load of the rope, independent of friction?

70 cwt. = 7,840 lbs.

Opposite angle 26 deg., in column 7, we find 981·94.

Then as 2240 : 981·94 :: 7840 : 3437 lbs., or 30 cwt., 2 qrs., 21 lbs. Then, by referring to the "Table of the Weight and Strength of Ropes," we shall ascertain the size of rope required for this work according to the makers' rule. (Due allowance must be made for friction, &c.)

COLUMN 8.—Everybody knows that there are 4,840 square yards in a statute acre; but in the case of property lying obliquely, which is not unfrequently so with coal seams, there is plainly an increase of superficial measure under a given area in proportion to the angle of elevation, so that the number of square yards in an acre of coal depends on the declivity.

The figures in this column show the ratio of increase from 1 to 50 deg., and are obtained by the following formula:—

$$\frac{1 \times 4840}{\text{cosine.}}$$

APPLICATION.—A colliery proprietor desires to know how many cubic yards of coal there are under twelve acres of land in a seam 6ft. thick, measured at right angles to the line of dip, the amount of which is uniformly 30 deg., which is supposed to be lying evenly and uninterruptedly throughout, and the whole of which will be won by a level at the lowest boundary.

The number of square yards in an acre per the table is 5588·78: thickness of seams two yards.

Then 5588·78 x 2 = 11177·56 cubic contents in yards per acre, and 11177·56 x 12 = 134130·72 total contents.

This result, we are aware, may be arrived at otherwise, namely, by measuring the thickness of the seam vertically.

This would be $\frac{6}{\cdot 86602}$ = 6·9282 ft., and $\frac{4840 \times 6 \cdot 9282}{3}$ = 11177·50 yards per acre, same as above very nearly.

TABLE SHOWING THE DIFFERENCE BETWEEN TRUE AND APPARENT LEVELS, IN FEET, CALCULATED BY THE FOLLOWING FORMULA:—

$$\frac{\text{Distance}^2}{\text{Diameter of earth.}}$$

The diameter of the earth, 7912 miles : $\frac{1}{7}$th deducted for refraction.

Distance in Chains.	Difference for Curvature.	Corrected for Refraction.	Distance in Miles.	Difference for Curvature.	Corrected for Refraction.
1	·000104	·000089	$0\frac{1}{4}$	0·042	0·036
2	·000417	·000358	$0\frac{2}{4}$	0·167	0 142
3	·000938	·000804	$0\frac{3}{4}$	0·375	0 322
4	·001668	·001430	1	0·667	0·571
5	·002605	·002233	2	2·667	2·285
6	·003752	·003216	3	6·000	5·150
7	·005107	·004378	4	10 675	9·150
8	·006670	·005717	5	16·675	14·292
9	·008442	·007236	6	24·008	20 578
10	·010422	·008933	7	32·683	28·014
11	·012610	·010809	8	42·692	36·593
12	·015007	·012863	9	54·025	46·307
13	·017613	·015097	10	66·700	57·171
14	·020427	·017509	11	80·708	69 178
15	·023450	·020100	12	96·050	82·329
16	·026780	·022869	13	112·717	96·615
17	·030120	·025817	14	130·733	112·057
18	·033623	·028943	15	150·075	128·638
19	·037567	·032248	16	170·750	146·357
20	·041687	·035732	17	192·767	165 229
21	·045960	·039394	18	216·108	185·235
22	·050442	·043236	19	240·783	206·385
23	·055132	·047259	20	266·800	228·686
24	·060031	·051455	Feet.		
25	·065137	·055832	500	0·00598	0·00513
26	·070452	·060388	1000	0·02598	0·02050
27	·075975	·065121	2000	0·09570	0·08206
28	·081708	·070036	3000	0·21533	0·18457
29	·087648	·075127	4000	0·38281	0·32812
30	·093798	·080399	5000	0·59814	0·51269

TABLE OF RAILWAY GRADIENTS, OR INCLINED PLANES.

Reduced to one in ten.

Feet per mile.	Inclination.	Inches per chain of 66 feet.	Feet per mile.	Inclination.	Inches per chain of 66 feet.
1	1 in 5280	0·15	42	1 in 125·7	6·30
2	1 in 2640	0·30	43	1 in 122·8	6·45
3	1 in 1760	0·45	44	1 in 120	6·60
4	1 in 1320	0·60	45	1 in 117·3	6·75
5	1 in 1056	0·75	46	1 in 114·8	6·90
6	1 in 880	0 90	47	1 in 112·3	7·05
7	1 in 754·2	1·05	48	1 in 110	7·28
8	1 in 660	1·20	49	1 in 107·7	7·35
9	1 in 586·6	1·35	50	1 in 105·6	7·50
10	1 in 528	1·50	51	1 in 103·5	7·65
11	1 in 480	1·65	52	1 in 101·5	7·80
12	1 in 440	1·80	53	1 in 99·6	7·95
13	1 in 406·1	1·95	54	1 in 97·8	8·10
14	1 in 377·1	2·10	55	1 in 96	8·25
15	1 in 352	2·25	56	1 in 94·3	8·40
16	1 in 330	2·40	57	1 in 92·6	8·55
17	1 in 310·6	2·55	58	1 in 91	8·70
18	1 in 293·3	2·70	59	1 in 89·5	8·85
19	1 in 277·9	2·85	60	1 in 88	9·00
20	1 in 264	3·00	61	1 in 86·5	9·15
21	1 in 251·4	3·15	62	1 in 85·1	9·35
22	1 in 240·4	3·30	63	1 in 83·8	9·40
23	1 in 229·5	3·45	64	1 in 82·5	9·65
24	1 in 220	3·60	65	1 in 81·2	9·70
25	1 in 211·2	3·75	66	1 in 80	9·90
26	1 in 203·1	3·99	67	1 in 78·8	10·5
27	1 in 195·5	4 05	68	1 in 77·6	10·20
28	1 in 138·6	4·20	69	1 in 76·5	10·35
29	1 in 182·1	4·35	70	1 in 75·4	10·50
30	1 in 176	4·50	71	1 in 74·3	10·65
31	1 in 170·3	4·65	72	1 in 73·3	10·80
32	1 in 165	4·80	73	1 in 72·3	10·95
33	1 in 160	4·95	74	1 in 71·3	11·10
34	1 in 155·3	5·10	75	1 in 70·4	11·25
35	1 in 150·8	5·25	76	1 in 69·4	11·41
36	1 in 146·6	5·40	77	1 in 68·5	11·56
37	1 in 142·7	5·55	78	1 in 67·7	11·70
38	1 in 138·9	5·70	79	1 in 66·8	11·85
39	1 in 135·4	5·85	80	1 in 66	12·
40	1 in 132	6·00	81	1 in 65·1	12·16
41	1 in 128	6·15	82	1 in 64·4	12·30

TABLE OF RAILWAY GRADIENTS, OR INCLINED PLANES.

(CONTINUED.)

Feet per mile.	Inclination	Inches per chain of 66 feet.	Feet per mile.	Inclination	Inches per chain of 66 feet.
83	1 in 63·6	12·45	240	1 in 22	36·
84	1 in 62·8	12·60	250	1 in 21·12	37·5
85	1 in 62·1	12·75	260	1 in 20·3	39·
86	1 in 61·4	12·90	270	1 in 19·55	40·5
87	1 in 60·6	13·5	280	1 in 18·85	42·
88	1 in 60	13·20	290	1 in 18	43·5
89	1 in 59·3	13·35	300	1 in 17·6	45·
90	1 in 58·6	13·50	310	1 in 17·3	46·5
91	1 in 58	13·65	320	1 in 16·5	48·
92	1 in 57·4	13·80	330	1 in 16	49·5
93	1 in 56·7	13·95	340	1 in 15·52	51·
94	1 in 56·1	14·10	350	1 in 15	52·5
95	1 in 55·5	14·26	360	1 in 14·66	54·
96	1 in 55	14·4	370	1 in 14·27	55·5
97	1 in 54·4	14·55	380	1 in 13·89	57·
98	1 in 53·8	14·7	390	1 in 13·53	58·5
99	1 in 53·3	14·85	400	1 in 13·2	60·
100	1 in 52·8	15·	410	1 in 12·87	61·5
110	1 in 48	16·5	420	1 in 12·59	63·
120	1 in 44	18·	430	1 in 12·27	64·5
130	1 in 40·61	19·5	440	1 in 12	66·
140	1 in 37·7	21·	450	1 in 11·75	67·5
150	1 in 35·2	22·5	460	1 in 11·47	69·
160	1 in 33	24·	470	1 in 11·23	70·5
170	1 in 31·05	25·5	480	1 in 11	72·
180	1 in 29·33	27·	490	1 in 10·77	73·5
190	1 in 27·78	28·5	500	1 in 10·56	75·
200	1 in 26·4	30·	510	1 in 10·35	76·5
210	1 in 25·14	31·5	520	1 in 10·15	78·
220	1 in 24	33·	528	1 in 10	79·2
230	1 in 22·95	33·5			

TABLES SHOWING THE TENACITY OF WROUGHT IRON AND STEEL.

Material	Tenacity in lbs. per square inch. Lengthwise.	Crosswise.	Authority
Wire—very strong, charcoal	114,000	... .	Morin
Wire—average	86,000	... .	Telford
Wire—weak	71,000	... .	Morin

TABLES SHOWING THE TENACITY OF WROUGHT IRON AND STEEL (CONTINUED.)

Material	Tenacity in lbs. per square inch. Lengthwise.		Crosswise.	Authority.
Yorkshire (Low Moor)	64,200	...	52,490	Fairbairn
" " from	66,390	...	.....	Kirkaldy
" " to	60,075	...	.....	
Yorkshire (Lower Moor) and Staffordshire rivet iron	59,750	...	.....	Fairbairn
Charcoal bar	63,620	...	.....	do.
Staffordshire bar.....from	62,231	...	.....	Kircaldy
to	56,715	...	.....	
Yorkshire bridge iron	49,930	...	43,940	Fairbairn
Staffordshire bridge iron	47,600	...	44,385	do.
Lanarkshire bar .....from	64,795	...	.....	Kirkaldy
to	51,327	...	.....	
Lancashire bar .....from	60,110	...	.....	do.
to	53,773	...	.....	
Swedish bar.....from	48,933	...	.....	do.
to	41,251	...	.....	
Russian bar .....from	59,096	...	.....	do.
to	49,564	...	.....	
Bushelled iron from turnings	55,878	...	.....	do.
Hammered scrap	53,420	...	.....	do.
Angle iron from various districts—				
from	61,250	...	.....	do.
to	50,056	...	.....	
Bessemer's iron, cast ingot	41,242	...	.....	Wilmot
Bessemer's iron, hammered or rolled	72,643	...	.....	do.
Bessemer's iron, boiler plate	68,319	...	.....	do.
Yorkshire plates.....from	58.487	...	55,033	Kirkaldy
to	52,000	...	46,221	
Staffordshire plates .....from	56.996	...	52,251	do.
to	46 404	...	44,764	
Staffordshire plates, best-best charcoal	45,010	...	41,420	Fairbairn
Staffordshire plates, best-best....from	59,820	...	54,820	do.
to	49,945	...	46,470	
Staffordshire plates, best	61,280	...	53,820	do.
Staffordshire plates, common	50,820	...	52,825	do.
Lancashire plates	48,865	...	45,015	do.
Lanarkshire plates.....from	53,849	...	48,848	Kirkaldy
to	43,433	...	39,544	

TABLES SHOWING THE TENACITY OF WROUGHT IRON AND STEEL (CONTINUED.)

Material	Tenacity in lbs. per square inch. Lengthwise.	Crosswise.	Authority.
Durham plates	51,245	46,712	Kirkaldy
Cast steel bars rolled & forged... from	132.909	... ...	do.
to	92,015	... ...	
Cast steel bars, rolled and forged	130,000	... ...	Rennie
Blistered steel bars, rolled & forged	104,290	... ...	Kirkaldy
Shear steel bars, rolled and forged	118,468	... ...	do.
Bessemer's steel bars, rolled & forged	111,460	... ...	do.
Bessemers's steel bars, cast ingots	63,024	... ...	Wilmot
Bessemer's steel bars, hammered or rolled	152,912	... ...	do.
Spring steel bars, hammered or rolled	72,529	... ...	Kirkaldy
Homogeneous metal bars, rolled	90,647	... ...	do.
Homogeneous metal bars, rolled	93,000	... ...	Fairbairn
Homogeneous metal bars, forged	89,724	... ...	Kirkaldy
Puddled steel bars, rolled and forged from	71,484	... ...	do.
to	62,768	... ...	
Puddled steel bars, rolled and forged	90,000	... ...	Fairbairn
Puddled steel bars, rolled and forged	94,752	... ...	Mallet.
Mushet's gun metal	103,400	... ...	Fairbairn
Cast steel plates ..... from	96,289	... 97,308	Kircaldy
to	75,594	... 69,082	
Cast steel plates ..... hard	102,900	... ...	Fairbairn
soft	85,400	... ...	
Homogenoous metal plates, first quality	96,280	... 97,150	Kirkaldy.
Homogeneous metal plates, second quality	72,408	... 73,580	do.
Puddled steel plates ..... from	102,593	... 85,365	do.
to	71,532	... 67,686	
Puddled steel plates	93,600	... ...	Fairbairn

TABLE OF THE RESISTANCE OF MATERIALS TO SHEARING, AND DISTORTION, in pounds avoirdupois per square inch (*Rankine*).

Materials.	Resistance to shearing	Transverse elasticity, or resistance to distortion.
Brass, wire-drawn	...	5,330,000
Copper	...	6,200,000
Iron, cast	27,700 ...	2,850,000
„ wrought	50,000 ...	8,500,000 to 9,500,000
Fir: red pine	500 to 800 ...	62,000 to 116,000
„ spruce	600 ...	.....
„ larch	970 to 1,700 ...	... .
Oak	2,300 ...	82,000
Ash and elm	1,400 ...	76,000

TABLE OF THE RESISTANCE OF MATERIALS TO STRETCHING AND TEARING BY A DIRECT PULL, in pounds avoirdupois, per square inch. (*Rankine.*)

Materials.	Tenacity, or resistance to tearing.	Modulus of elasticity, or resistance to stretching.
Brass, cast	18,000 ...	9,170,000
„ wire	49,000 ...	14,230,000
Copper, cast	19,000 ...	
„ sheet	30,000 ...	
„ bolts	36,000 ...	
„ wire	60,000 ...	
Iron, cast, various qualities	13,400 to 29,000 ...	14,000,000 to 22,900,000
„ average	16,500 ...	17,000,000
Iron, wrought, plates	51,000 ...	
„ joints, double rivetted	35,700 ...	
„ „ single rivetted	28,600 ...	
„ bars and bolts	60,000 to 70,000 ...	29,000,000
„ hoop, best-best	64,000	
„ wire	70,000 to 100,000 ...	25,300,000
„ wire ropes	90,000 ...	15,000,000
Steel bars	100,000 to 130,000 ...	29,000,000 to 42,000,000
Steel plates, average	80,000 ...	

RESILIENCE OF IRON AND STEEL. *(Rankine.)*

Metal under tension.	Ultimate tenacity.	Working tenacity.	Modulus of elasticity.	Modulus of resilience.
Cast-iron, weak	13,400	4,467	14,000,000	1·425
„ average	16,500	5,500	17,000,000	1·78
„ strong	29,000	9,667	22,900,000	4·08
Bar iron, good average	60,000	20,000	29 000,000	13·79
Plate iron „	50,000	16,667	24,000.000?	11.57?
Iron wire „	90,000	30,000	25,300,000	35·55
Steel, soft	90,000	30,000	29.000.000	31·03
„ hard	132,000	44,000	42,000,000	46·10

NOTE.—In the above table of resilience, the working tenacity is for a "dead" or steady load. The modulus of resilience is calculated by dividing the square of that working tenacity by the modulus of elasticity.

TABLE OF THE RESISTANCE OF MATERIALS TO BREAKING ACROSS, in pounds avoirdupois per square inch. *(Rankine.)*

NOTE.—The modulus of rupture is eighteen times the load which is required to break a bar of one inch square, supported at two points one foot apart, and loaded in the middle between the points of support.

Materials.	Resistance to breaking, or modulus of rupture.
Sandstone	1,100 to 2,360
Slate	5,000
Iron, cast, open-work beams, average	17,000
„ solid rectangular bars, various qualities	33,000 to 43,500
„ „ „ „ „ average	40,000
„ wrought, plate beams	42,000
Ash	12,000 to 14.000
Beech	9,000 to 12,000
Birch	11,700
Elm	6.000 to 9,700
Fir: red pine	7,100 to 9,540
„ spruce	9,900 to 12,300
„ larch	5,000 to 10,000
Lancewood	17,350
Lignum-vitæ	12,000
Oak, British and Russian	10,000 to 13,600
„ Dantzic	8,700
„ American red	10,600
Sycamore	9,600
Teak, Indian	12,000 to 19,000

TABLE OF THE RESISTANCE OF MATERIALS TO CRUSHING BY A DIRECT THRUST, in pounds avoirdupois per square inch. (*Rankine.*)

Materials.	Resistance to crushing.
Brick, weak red	550 to 800
„ strong red	1,100
„ fire	1,700
Chalk	330
Granite	5,500 to 11,000
Limestone, marble	5,500
„ granular	4,000 to 4,500
Sandstone, strong	5,500
„ ordinary	3,300 to 4,400
„ weak	2,200
(Rubble masonry, about four-tenths of cut stone.)	
Brass, cast	10,300
Iron, cast, various qualities	82,000 to 145,000
„ „ average	112,000
„ wrought	about 36,000 to 40,000
Ash crushed along the grain	9,000
Beech „ „	9,360
Birch „ „	6,400
Box „ „	10,300
Elm „ „	10,300
Fir: red pine „ „	5,375 to 6,200
„ American yellow pine „ „	5,400
„ larch „ „	5,750
Lignum-vitæ „ „	9,900
Mahogany „ „	8,200
Oak, British „ „	10,000
„ Dantzic „ „	7,700
„ American red „ „	6,000
Teak, Indian „ „	12,000

NOTE.—The resistances stated are for *dry* timber. Green timber is much weaker, having sometimes only half the strength of dry timber against crushing.

EFFECTS OF RE-HEATING AND ROLLING (*according to clay.*)

Puddled bar	43,904	Tenacity in pounds per square inch lengthwise.
The same iron five times piled, re-heated, and rolled	61,824	
The same iron eleven times piled, re-heated and rolled	43,904	

CHEMICAL MEMORANDA.

A simple or elementary substance is a body that cannot be resolved or separated into any simpler substance—as oxygen, carbon, iron.

A compound substance is one consisting of two or more constituents—as water, carbonic acid gas, olefiant gas.

The equivalent number or atomic weight expresses the relation that subsists between the different proportions by weight in which substances unite chemically with each other.

The equivalent of a compound is the sum of the equivalents of its constituents.

Specific gravity expresses the difference that subsists between the weights of equal volumes of bodies.

So far as chemists have been able to discover, there are about 65 elementary or simple substances.

No compound body contains all the elementary substances. Most compounds are composed of two, three, or four elements.

TABLE OF ELEMENTARY SUBSTANCES.

Names of Elements.	Symbol.	Atomic Weight.	Names of Elements.	Symbol.	Atomic Weight
Aluminum	Al	27·4	Nickel	Ni	58·8
Antimony	Sb	122	Niobium	Nb	95
Arsenic	As	75	Nitrogen	N	14
Barium	Ba	137	Osmium	Os	199
Beryllium	Be	9·4	Oxygen	O	16
Bismuth	Bi	210	Palladium	Pd	106·6
Boron	B	11	Phosphorus	P	31
Bromine	Br	80	Platinum	Pt	197·4
Cadmium	Cd	112	Potassium	K	39·1
Calcium	Ca	40	Rhodium	R	104
Carbon	C	12	Rubidium	Rb	85
Cerium	Ce	92	Ruthenium	Ru	104
Chlorine	Cl	35·5	Selenium	Se	79
Chromium	Cr	52·2	Silicium or Silicon	Si	28
Cobalt	Co	58·8	Silver	Ag	108
Copper	Cu	63·4	Sodium	Na	23
Fluorine	F	19	Strontium	Sr	87·6
Gold	Au	197	Sulphur	S	32
Hydrogen	H	1	Tantalum	Ta	182
Indium	In	74	Tellurium	Te	128
Iodine	I	127	Thallium	Tl	204
Iridium	Ir	198	Thorium	Th	231·5
Iron	Fe	56	Tin	Sn	118
Lanthanum	Ln	93	Titanium	Ti	50
Lead	Pb	207	Tungsten	W	184
Lithium	Li	7	Uranium	U	120
Magnesium	Mg	24	Vanadium	V	51·2
Manganese	Mn	55	Yttrium	Y	61·7
Mercury	Hg	200	Zinc	Zn	65
Molybdenum	Mo	96	Zirconium	Zr	89·6

NOMENCLATURE.

The compounds of the non-metallic elements with the metals and with each other, have names ending in "ide" or "uret," as Fe S. sulphide or sulphuret of iron.

When two or more equivalents of the non-metallic elements enter into combination, the number of equivalents is expressed by prefixes.

Bi means 2 eq., as $N O_2$ binoxide of nitrogen.

Ter „ 3 eq., as $Sb_2 S_3$ tersulphide of antimony.

Penta „ 5 eq.

Sesqui„ $1\frac{1}{2}$ eq. (= 2 to 3), as $Fe_2 O_3$ sesquioxide of iron.

Proto „ first, or 1 to 1, as Fe O protoxide of iron.

Sub „ under, as $Cu_2 O$ suboxide of copper.

Per „ the highest, as $Cl O_4$ peroxide of chlorine.

Alkalies neutralise acids, forming salts.

The terminations "ic" and "ous" are used for acids, the former representing a higher state of oxidation than the latter.

When a substance forms more than two acid compounds, the prefixes "hypo" *under*, and "hyper" *above*, are used.

A base is a compound which will chemically combine with an acid.

A salt is a compound of an acid and a base.

When water is in combination with acids or bases, they are said to be hydrated.

LIST OF SOME BINARY COMPOUNDS.

Name of Compound.	Symbol.
Ammonia	$N H_3$
Bisulphide of carbon	$C S_2$
Carbonic acid gas	$C O_2$
Carbonic oxide	$C O$
Cyanogen	$N C_2$
Hydrochloric acid	$H Cl$
Light carburetted hydrogen	$C H_4$
Nitric acid	$N O_5$
Olefiant gas	$C_2 H_4$
Peroxide of iron	$Fe_2 O_3$
Protoxide of iron	$Fe O$
Sulphurous acid gas	$S O_2$
Sulphuric acid	$H_2 SO_4$
Sulphuretted hydrogen	$H_2 S$
Water	$H_2 O$

COMMON NAMES OF CERTAIN CHEMICAL SUBSTANCES.

Aqua fortis	Nitric acid
Bluestone, or blue vitriol	Sulphate of copper
Calomel	Chloride of mercury
Chloroform	Chloride of formyle
Common salt	Chloride of sodium
Copperas, or green vitriol	Sulphate of iron
Corrosive sublimate	Bichloride of mercury
Dry alum	Sulphate of alumina and potash
Epsom salts	Sulphate of magnesia
Ethiops mineral	Black sulphide of mercury
Galena	Sulphide of lead
Glauber's salts	Sulphide of soda
Iron pyrites	Bisulphide of tin
Jeweller's putty	Oxide of tin
King's yellow	Sulphide of arsenic
Laughing gas	Protoxide of nitrogen
Lime	Oxide of calcium
Lunar caustic	Nitrate of silver
Mosaic gold	Bisulphide of tin
Nitre, or saltpetre	Nitrate of potash
Oil of vitriol	Sulphuric acid
Realgar	Sulphide of arsenic
Red lead	Oxide of lead
Rust of iron	Oxide of iron
Soda	Oxide of sodium
Spirit of hortshorn	Ammonia
Spirit of salt	Hydrochloric acid
Stucco, or plaster of Paris	Sulphate of lime
Sugar of lead	Acetate of lead
Vermilion	Sulphide of mercury
Vinegar	Acetic acid
Volatile Alkali	Ammonia
Water	Oxide of hydrogen
White Vitriol	Sulphate of zinc

TABLE OF THE RELATIVE POWER OF METALS FOR CONDUCTING HEAT.

Gold	1000	Iron	374·3
Silver	973	Zinc	363
Copper	898·2	Tin	303·9
Platinum	381	Lead	179·6

TABLE SHOWING THE NUMBER OF VOLUMES OF VARIOUS GASES WHICH 100 VOLUMES OF WATER, AT 60 DEG. FAHR. AND 30 INCHES BAROMETRIC MEASURE, CAN ABSORB.

(Dr. Frankland).

Ammonia	7800 volumes.
Sulphurous acid	3300 ,,
Sulphuretted hydrogen	253 ,,
Carbonic acid	100 ,,
Olefiant gas	12·5 ,,
Illuminating hydrocarbons	Not determined, but probably more soluble than olefiant gas.
Oxygen	3·7 volumes.
Carbonic acid	1·56 ,,
Nitrogen	1·56 ,,
Hydrogen	1·56 ,,
Light carburetted hydrogen	1·60 ,,

When water has been saturated with one gas and is exposed to the influence of a second, it usually allows a portion of the first to escape whilst it absorbs an equivalent quantity of the second In this way, a small portion of a not easily soluble gas can expel a large volume of an easily soluble one.

	Spec. Grav.
Atmospheric air	1·000
Oxygen gas	1·106
Nitrogen gas	0·972
Carbonic acid gas	1·524

TABLE OF THE LINEAL EXPANSION OF METALS PRODUCED BY RAISING THEIR TEMPERATURE FROM 32 deg. to 212 deg. FAHR.

Zinc	1 part in 322	Gold	1 part in 682
Platinum	,, 351	Bismuth	,, 719
Tin (pure)	,, 403	Iron	,, 812
Tin (impure)	,, 500	Antimony	,, 923
Silver	,, 524	Palladium	,, 1000
Copper	,, 581	Platinum	,, 1100
Brass	,, 584	Flint Glass	,, 1248

Expansion of Liquids in Volume from 32 deg. to 212 deg. Fahr.

1,000 parts of	water	become	1,046
,,	oil	,,	1,080
,,	mercury	,,	1,018
,,	spirits of wine	,,	1,110
,,	air	,,	1,373

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EXTRACTS FROM TESTIMONIALS.

Dear Sir, *11th October, 1874.*

I have read your work on mines; it is the best work I ever read, and deserves to be circulated in every Colliery district, for the safety of miners. I have had twenty years' practice in the management of Mines.

Swadlincote Colliery. Yours, &c., JOSEPH EAMES.

Sir, *January 18th, 1866.*

I worked at Mr. Ackroyd's Colliery when you had the management. found you a man both in knowledge and principle. I am in a situation as underground Viewer, but deficient in knowledge of many things. I ask help, knowing there is no one more able than you to give it. I had two men from home (England), with two copies of your work, but they would not sell one at any price. Send me a copy, if possible, I will also forward you money for instruments to survey and plan with; be kind enough to purchase suitable ones for me.

Gowerie Mines, Cow Bay, Cape Breton, British North America. CHARLES INMAN.

Sir, *15th December, 1864.*

I have read your "Conversation on Mines." I must confess I have learnt many things I never knew before, for which I desire to return my humble thanks for the instructions received. HENRY LOWERY,

Deputy at Rainton Colliery, Durham.

The Colliery Guardian.—*20th August, 1864.*

A Conversation on Mines, &c., between Father and Son, by William Hopton, Colliery Manager, St. Helens, Lancashire.—This is an excellent little book, designed especially for the instruction of working miners, by one who is well acquainted with their wants, and evidently knows how to supply them. We cordially commend this little manual to the subordinate officers in collieries, and indeed to every working miner. Let them purchase it, and employ their leisure in mastering its contents, and they will find that both the money and the time have been well spent. Such a work, well understood by every miner, would do more to prevent colliery accidents than any army of inspectors, and to raise the collier in the social scale than all the efforts of unions and all the vague declamations of delegates.

Mining Journal—*18th July, 1864.*

PRACTICAL COLLIERY WORKINGS.—Under the title of "A Conversation on Mines between a Father and Son," Mr. William Hopton, Colliery Manager, St. Helens, Lancashire, has issued a neat little volume, the object of which is to provide a work for practical colliers, written in a style which can be readily understood by them.

Mr. Hopton begins with supplying the elements of those natural laws upon which the safe working of collieries depends, and gradually leads the reader on until not only good methods of laying out and ventilating collieries are thoroughly understood, but until the dialling of a mine and the preparation of a plan can be undertaken with the utmost confidence. The book is one which cannot fail to be well received by all connected with collieries, and at the same time, it reflects great credit upon the author.

St. Woolos Road, Newport—*July 18th, 1864.*

To Mr. J. J. Campbell.

Sir,—I beg to acknowledge having received the Treatise on Mining by Mr. Hopton, for which I am obliged; and beg to say, as a practical man for a great number of years, that it is the best work of the sort I have seen for the class of men it is intended for; and shall have great pleasure in recommending it to all who may require a knowledge of the subject.

Yours truly, CHRISTOPHER FIRBANK.

P.S.—I will strongly recommend the work.—C. F.

Dear Sir,—I am an under-viewer, and have had upwards of twenty years' experience. I find it a very valuable little work for me, and worth the notice of experienced men, and no doubt Mr. Hopton is a man thoroughly up to the mark.

I am, yours respectfully, JOHN TRUMAN.

Swadlincote Old Colliery, near Burton-on-Trent,
27th July, 1864.

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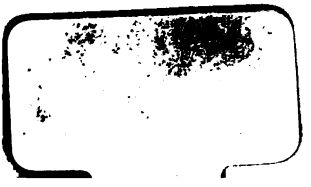
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